CONSULTANT REPORT

PIER
Public Interest Energy Research
CALIFORNIA ENERGY COMMISSION

Strategic Energy Research

INTELLIGENT SOFTWARE AGENTS FOR CONTROL AND SCHEDULING OF DISTRIBUTED GENERATION

Gray Davis, *Governor*

MARCH 2001

CALIFORNIA ENERGY COMMISSION

RESOURCES AGENCY

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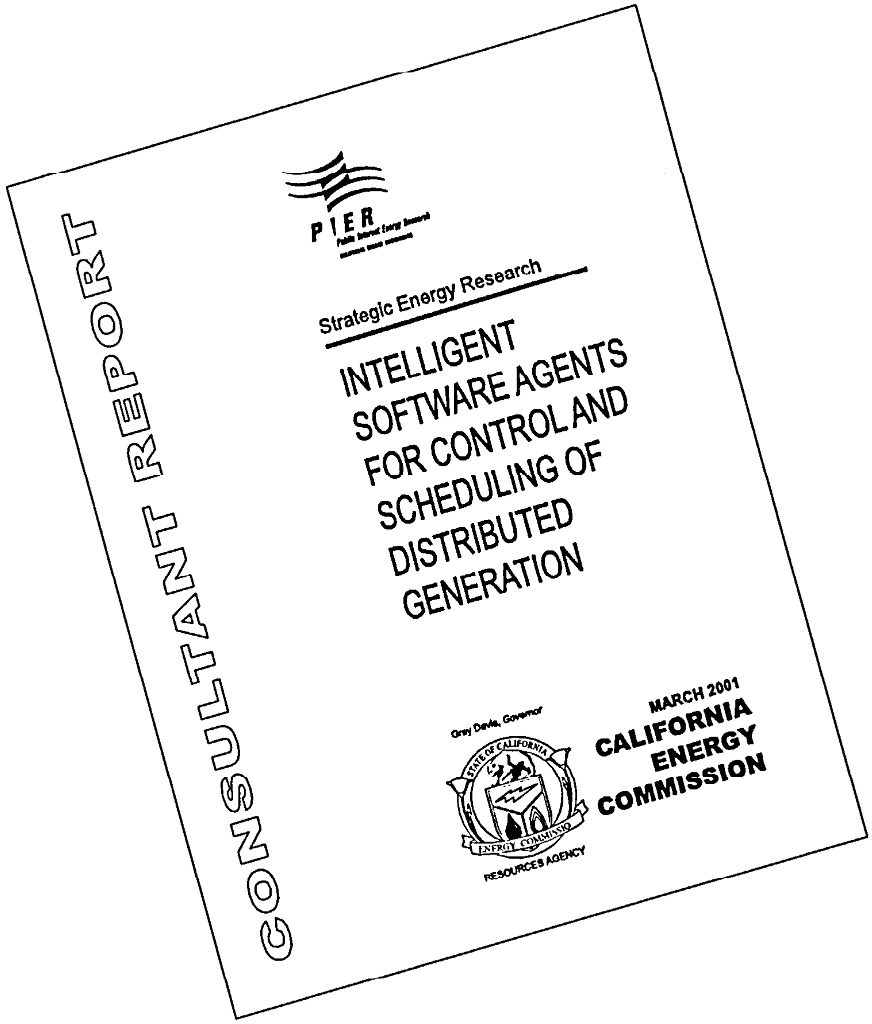
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CALIFORNIA ENERGY COMMISSION

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Legal Notice

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Preface

The Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The PIER Program, managed by the California Energy Commission (Commission), annually awards up to $62 million to conduct the most promising public interest energy research by partnering with Research, Development, and Demonstration (RD&D) organizations, including individuals, businesses, utilities, and public or private research institutions.

PIER funding efforts are focused on the following six RD&D program areas:

- Buildings End-Use Energy Efficiency
- Industrial/Agricultural/Water End-Use Energy Efficiency
- Environmentally-Preferred Advanced Generation
- Energy-Related Environmental Research
- Renewable Energy
- Strategic Energy Research.

What follows is the final report for the Intelligent Software Agents for Control and Scheduling of Distributed Generation contract, contract number 500-98-040, conducted by Alternative Energy Systems Consulting, Inc. The report is entitled Intelligent Software Agents for Control and Scheduling of Distributed Generation. This project contributes to the Strategic Energy Research program.

For more information on the PIER Program, please visit the Commission's Web site at: http://www.energy.ca.gov/research/index.html or contact the Commission's Publications Unit at 916-654-5200.

Executive Summary

One need only look at the daily newspaper to appreciate the dynamic nature of California's energy markets. The imbalance between available energy supplies and increasing energy demand have necessitated rolling blackouts and renewed requests for conservation. The use of Distributed Energy Resources to help defer the need for construction of large generating stations has long been recognized as a means of improving this situation. A Distributed Energy Resource (DER) is an efficient electrical generation or storage device that, unlike large central generating plants, can be remotely located and is often sited on a customer's site. In addition, numerous benefits studies have shown that DER technology improves the reliability and cost effectiveness of electric distribution systems. While it was clear that DER assets could play a significant role in a competitive energy market, there were formidable barriers to its use. DER technology requires control and scheduling of large numbers of distributed assets, but the centralized decision and control paradigm employed in the electric power industry is ill suited to this task.

In response to this need the California Energy Commission (Commission) contracted with Alternative Energy Systems Consulting, Incorporated (AESC) as part of a Public Interest Energy Research (PIER) project that addressed this problem using a new and innovative approach. The primary goal of this highly successful PIER project titled, "Intelligent Software Agents for Control & Scheduling of Distributed Generation" was to demonstrate the viability of using intelligent software agents for control and scheduling of one or more distributed energy resources in California's competitive energy market.

At its most basic level, an intelligent software agent is software programmed to act on behalf of the user. Software agents have a number of capabilities including the ability to operate autonomously, monitor their environment and communicate with others (agents or the user). Intelligent agent technology represents a fundamentally different way of addressing the DER asset-scheduling problem. Use of intelligent agent technology provides for a distributed decision-making solution where centralized decision making processes are currently being applied. This fundamental shift in thinking makes the job of transferring this technology into the private sector more difficult since it requires that potential users change the way that they view the problem (and solution). Therefore, the project technical objectives were structured to address this issue by demonstrating the viability of this technology along with the basic tools (i.e., demonstration software, test reports, etc.) needed to facilitate transfer of this technology into the energy industry. To facilitate the eventual commercialization of this technology the economic objective required that AESC identify and initiate discussions with one or more potential partners willing and able to participate with continued commercialization of the intelligent agent approach.

Objectives

The technical and economic objectives of this project were to:

- Demonstrate how a prototype network of intelligent software agents can coordinate and schedule one or more distributed energy resources.
- Develop a demonstration package that will facilitate transfer of the project results into the private sector.
- Identify and initiate discussions with one or more potential partners who are willing and able to participate with commercialization of *Smart**DER technology.

Outcomes

AESC achieved the project's objectives:

- Successfully demonstrated how a prototype network of intelligent software agents (*Smart**DER), communicating over the Internet and operating without direct human intervention can coordinate and schedule one or more distributed energy resources.
- Developed a demonstration package that will facilitate transfer of the project results into the private sector.
- Identified and initiated discussions with one or more potential partners who are willing and able to participate with commercialization of *Smart**DER technology.

Conclusions

- Intelligent agent technology represents a fundamentally different way of addressing the DER asset-scheduling problem. Use of intelligent agent technology provides for a distributed decision-making solution where centralized decision making processes are currently being applied. This fundamental shift in thinking makes the job of transferring this technology into the private sector more difficult since it requires that potential users change the way that they view the problem (and solution).
- During the project AESC succeeded in bringing this intelligent-agent technology to a Stage 3 (Bench testing / proof of concept) level of development. Thus demonstrating the potential of this technology to radically change the way that DER assets are dispatched in the California marketplace. In addition, AESC laid the groundwork for further development beyond Stage 3 by developing and demonstrating software that can be used to facilitate the Stage 4, Product Development and Field Experiments as well as establishing dialogues with potential commercialization partners.

Benefits to California

There is little question that integration of DER assets into the marketplace, the overriding premise behind this PIER project, continues to be of paramount importance. Intelligent software agents with their ability to communicate and collaborate are well suited to the task of scheduling and coordinating the activities of large numbers of DER assets. Use of intelligent software agents in this fashion reduces the level of expertise needed to own and operate distributed energy resources, which in turn, allows greater participation by owners of distributed energy resources in California's competitive energy industry. The benefits of this project are therefore tied to the benefits of increased DER participation in California’s deregulated marketplace:

- Improved system reliability, power quality, VAR control, and reduced reliance on must-run generation
- Reduced distribution system congestion, avoidance of distribution line losses and deferral of system upgrade / construction
- Customer cost reduction by direct displacement of load
- Energy price reduction (as new DER assets displace existing load and / or centralized generation)

Recommendations

AESC recommends that the Commission fund a follow-on PIER effort that would move this technology forward to completion of Stage 4. This effort would involve the following:

- Review and Evaluate the Feedback from the existing project,
- Identify Feasibility Field Test Participants,
- Refine the *Smart**DER Technology and Integrate / Interface it with existing network infrastructure software products,
- Conduct a Feasibility Field Test For Control of Actual Loads

For Additional Information

For additional information on application of *Smart**DER technology or the potential benefits of applying intelligent software agents in general contact:

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Abstract

The use of Distributed Energy Resources (DER) to help defer the need for construction of large generating stations has long been recognized as a means of improving the serious imbalance that exists in the competitive California energy markets. Use of DER technology requires control and scheduling of large numbers of distributed assets yet the centralized control paradigm employed in the electric power industry is ill suited to this task. In response to this need the Commission contracted with Alternative Energy Systems Consulting, Incorporated (AESC) as part of a PIER project that addressed this problem using a new and innovative approach. The primary goal of this PIER project titled, "Intelligent Software Agents for Control & Scheduling of Distributed Generation" was to demonstrate the viability of using intelligent software agents for control and scheduling of distributed energy resources in California's competitive energy market.

During this highly successful project, AESC and its principal subcontractor, Reticular Systems, succeeded in bringing this intelligent-agent technology to a Stage 3 (Bench testing / proof of concept) level of development. Testing confirmed that use of *Smart**DER™ agents could enable sites with excess generating capacity to collaborate via the Internet and aggregate this capacity for participation in the Ancillary Services (AS) markets operated by the California Independent System Operator (CAISO). In other words, testing showed that *Smart**DER technology could bring generating capacity to the California marketplace that may not otherwise have been able to participate.

During the course of the project AESC established dialogues with potential commercialization partners that expressed an interest in moving this technology forward. AESC therefore recommended that the Commission fund a follow-on PIER effort that would move this technology forward to completion of Stage 4 and more specifically to conduct a feasibility field test for control of actual loads and generation assets.

Keywords: distributed generation, distributed energy resources, software agents, resource scheduling, and resource dispatch

1.0 Introduction

This report has been prepared by Alternative Energy Systems Consulting, Incorporated (AESC) as part of a California Energy Commission (Commission) Public Interest Energy Research (PIER) project titled, “Intelligent Software Agents for Control & Scheduling of Distributed Generation”. The overall goal of this PIER project was to demonstrate the viability of using intelligent software agents for control and scheduling of one or more distributed energy resources (e.g., distributed generation, energy storage, cogeneration, curtailable loads, etc.) in a competitive energy market.

1.1 Background

A Distributed Energy Resource (DER) is an efficient electrical generation or storage device that, unlike large central generating plants, can be remotely located and is often sited on a customer’s site. Numerous benefits studies have shown that DER technology improves the reliability and cost effectiveness of electric distribution systems. CADER (California Alliance for Distributed Energy Resources) summarized these benefits[2] as:

- Improved system reliability, power quality, VAR control, and reduced reliance on must-run generation
- Reduced distribution system congestion, avoidance of distribution line losses and deferral of system upgrade/construction
- Customer cost reduction by direct displacement of load
- CalPX market clearing price (MCP) reduction (new DER reduces overall system demand which displaces the highest cost resource)

While it is clear that DER assets can play a significant role in a competitive energy market there are significant barriers to the use of this technology. Use of DER technology requires control and scheduling of large numbers of distributed assets. The centralized decision and control paradigm employed in the electric power industry is ill suited to this task.

1.1.1 What is an Intelligent Agent?

At its most basic level, an intelligent agent is a software-based device that acts on behalf of the user. Software agents have a number of capabilities including the ability to monitor their own execution environment, communicate with other agents or the user and maintain some representation of their own internal mental state. Software agents are characterized by their ability to operate autonomously. This means that after an agent starts executing, no further interventions are required from the user. An autonomous agent is able to complete its task on its own.

Software agents can be used in a wide variety of applications. An intelligent software agent can contain significant amounts of expertise and can be applied in systems requiring planning or learning capabilities. Agents are particularly useful in applications

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[2] See CADER Collaborative Report and Action Agenda, January 1998

involving machine to machine or man to machine communications. One popular use of agents is information seeking and cataloging on the Internet. Agents can be used in applications where they learn about an individual user and modify their own behavior to suit the information-seeking needs of the user. Agents are also useful in applications where multiple agents can communicate and cooperate with other agents for solving a given problem. These agents can be physically located on the same computer or distributed in a variety of locations. Multiple agents operating in conjunction, as an agency, can achieve goals and objectives that would not be otherwise achievable by a single agent.

Use of intelligent software agents with their ability to communicate and collaborate thus distributing the decision process, is well-suited to the task of scheduling and coordinating the activities of large numbers of DER assets. Use of agents in this fashion reduces the level of expertise needed to own and operate distributed energy resources, which in turn, allows greater participation by owners of distributed energy resources in California's competitive energy industry.

1.2 Project Approach

The project approach can be divided into three basic task areas. Two areas, Project Start-up Tasks and Project Reporting Task pertain to the project management and reporting efforts required of all PIER projects while the third area, Technical Tasks deals with the effort to develop and test the *Smart**DER agent based technology.

1.3 Project Start-Up Tasks

AESC hosted a project kick-off meeting at its San Diego offices on June 9, 1999 to formally begin the project efforts. Project objectives, tasks and the associated schedule/budget were reviewed with the Commission Contract Manager. Just prior to the meeting AESC formally documented the planned matching contributions from both AESC and its principal subcontractor, Reticular Systems in correspondence dated June 8, 1999. In addition, AESC documented the fact (correspondence dated June 8, 1999) that no permits would be needed during the course of the project.

1.4 Project Objectives

Intelligent agent technology represents a fundamentally different way of addressing the DER asset-scheduling problem. Use of intelligent agent technology provides for a distributed decision-making solution where centralized decision making processes are currently being applied. This fundamental shift in thinking makes the job of transferring this technology into the private sector more difficult since it requires that potential users change the way that they view the problem (and solution). The technical objectives of this project were structured to address this issue by demonstrating the viability of this technology along with the basic tools (i.e., demonstration software, test reports, etc.) needed to facilitate transfer of this technology into the energy industry.

The technical and economic objectives of the existing project are to:

- Demonstrate how a prototype network of intelligent software agents can coordinate and schedule one or more distributed energy resources.
- Develop a demonstration package that will facilitate transfer of the project results into the private sector.
- Identify and initiate discussions with one or more potential partners who are willing and able to participate with commercialization of the DER*S agency.

1.5 Report Organization

The remainder of this Final Project Report is organized into four main sections. The first section, Section 1, Introduction, briefly describes the basic project approach and project tasks, Section 2, Discussion, describes both the approach and results by task. Section 3, Project Outcomes, is divided into two basic subsections, one describing outcomes by project technical objective and the second by describing the outcomes pertaining to the project economic objective. Section 4.0 presents conclusions and recommendations derived from the project.

2.0 Discussion

Project technical efforts were divided into the following five tasks (excluding Project Management efforts):

1 Domain Analysis and Market Research

2 DER*S Agency Development and Testing

3 EASE Development and Testing

4 *Smart**DER – EASE Integration and Testing

5 *Smart**DER Documentation and Demonstration Development

Project tasks are shown graphically in Figure 1. As the figure shows, some of the project tasks occurred concurrently thus allowing for a shorter overall development period. Specific task descriptions follow.

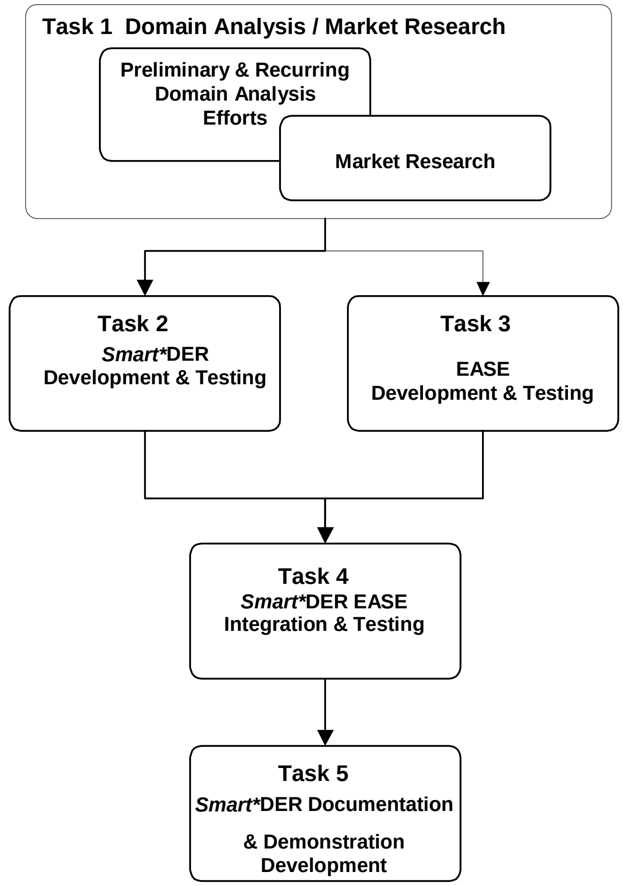


Figure 1. Project Technical Task Flow

2.1 Task 1 Domain Analysis and Market Research

The purpose of this task was to evaluate the California energy market as it relates to the operation of distributed energy resources in order to describe the environment, or domain, in which the agents and agency developed in this project must operate.

This task was divided into two separate but interactive efforts: domain analysis and market research. In the initial domain analysis effort we examined the energy industry domain as it related to our planned development of an agent and agency for scheduling of distributed energy resources. Thus we were able to characterize the *Smart**DER operating environment. This effort yielded a preliminary description of the *Smart**DER concept along with questions/issues requiring additional investigation.

During the market research effort we identified key market participants who were willing to share their views on distributed energy resources in the deregulated energy environment. Having identified questions and issues during the initial domain analysis phase, we solicited feedback from market participants to answer these questions and resolve the open issues and to set broad goals and objectives for the final product. This group of market participants became our Virtual Evaluation Group (Appendix III) and provided feedback both during this market research task and throughout the remainder of the project. Another objective of the market research task was to identify potential commercialization partners for *Smart**DER technology that could also participate in our Virtual Evaluation Group of market participants.

AESC provided the following deliverables as part of the Task 1 effort:

- Preliminary Domain Analysis Report
- List of Market Participants
- Project Summary Description (used for contacting / informing Market Participants)
- Market Research Report
- Final Domain Analysis Report

The Commission Contract Manager conducted the first Critical Project Review at the conclusion of this task.

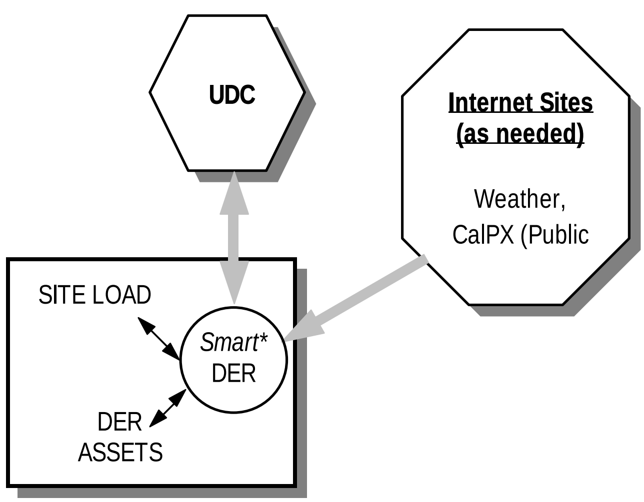
2.1.1 Task 1 Results

The preliminary domain analysis was the first task in the PIER project. In this task AESC analyzed the California energy industry in order to characterize the potential *Smart**DER markets (e.g., end-users / potential owners, benefits and capabilities). The results of this analysis effort were summarized in the Preliminary Domain Analysis Report. During the preliminary domain analysis effort AESC identified basic *Smart**DER operating scenarios based on analysis of the current energy marketplace in California, potential DER technologies and their potential benefits. As part of the market research effort, AESC formed a market participant evaluation group comprised of key individuals and companies that operate in, or have knowledge of, the competitive energy industry and / or distributed energy resources. The market participant evaluation group provided vital feedback on key issues and questions raised in the preliminary domain analysis. Specifically, the market participant group was used to prioritize the potential *Smart**DER markets. Results of this market research effort were summarized in the Market Research Report (Appendix I). Ultimately, our objective was to characterize the *Smart**DER operating environment, or domain, for the most likely *Smart**DER markets. Results of the Domain Analysis effort were summarized in the Final Domain Analysis Report (Appendix II).

We concluded from our analysis that *Smart**DER is only applicable to DER equipment that can be dispatched. Non-dispatchable technologies, such as wind, solar, and energy efficiency, are not compatible with *Smart**DER because their production output is not controllable. However, in some DER technologies, the addition of energy storage *can* provide dispatching capability. Other DER technologies such as ultra-capacitors and SMES provide short bursts (i.e., milliseconds) of electric energy to improve power quality. Although dispatchable, these technologies are triggered by power quality events and do not affect the aggregate value of electric energy. Curtailable loads are dispatchable but to varying degrees depending on the type of load involved. For example, remote control of cycling of residential or small commercial air conditioners is a dispatchable resource that could be bid into the ancillary services market as non-spinning reserve (available within 10 minutes). Loads (i.e., process loads, etc.) requiring additional time could still be classified and scheduled / dispatched as replacement reserves (available within 60 minutes).

Entities that could benefit from *Smart**DER operation are envisioned as building owners / operators, ESCOs (or other load aggregator) or Utility Distribution Companies (UDC). A building owner / operator could benefit by using DER scheduling to lower overall energy costs and increase power supply reliability. An ESCO (or other load aggregator) could use *Smart**DER for bundling of customer on-site DER services with power and fuel contracts to increase customer value and improve contract margins. *Smart**DER could also enable building owners / operators and ESCOs to bid into one or more of the California energy or ancillary services markets. UDC participation in *Smart**DER applications may be based on a connection between potential DER benefits and UDC Performance Based Ratemaking (PBR) mechanisms. Several studies have identified power delivery cost and performance benefits derived from DER installations and past studies by the Electric Power Research Institute (EPRI), Pacific Gas and Electric (PG&E) and others have identified potential UDC benefits from DER that include; capital deferral, reduced energy loss and improved reliability. Direct UDC ownership of DER assets continues to be the subject of debate. Therefore, in the near-term it is unlikely that a UDC will own or operate DER assets, however this could change as the marketplace continues to evolve.

The *Smart**DER operating environment can vary significantly in terms of the number and types of entities that are involved. Based on our assessment of the California marketplace we believe that there are three basic *Smart**DER operating scenarios, each with a differing level of complexity. In the first scenario (Figure 2), *Smart**DER agents



operate one or more DER assets at a single site to minimize site energy costs.

Figure 2. Single Site Operation

Agents(s) monitor site load and DER performance and access weather data via the Internet in order to predict site loads. In addition, or in lieu of this information, agents may receive pricing signal(s) from the local UDC depending on the applicable electric rate. Electricity and possibly natural gas prices (depending on the DER asset involved) could also be accessed via the Internet as needed. In this scenario *Smart**DER agents operate the DER asset to reduce on-site loads and associated costs without any direct involvement in the various energy and demand markets. Note that this operating scenario could also apply to *Smart**DER scheduling / dispatching of DER assets installed at a substation with UDC operation / ownership of *Smart**DER (if UDC ownership / operation of DER assets is permitted).

The second scenario (Figure 3) provides for *Smart**DER aggregation of multiple assets without direct involvement in any of the competitive markets. Under this operating scenario *Smart**DER agents aggregate load or otherwise coordinate operation of DER assets at multiple sites. This would allow sites / businesses to respond to interruptible rates or could provide an ESCO with load shaping capabilities.

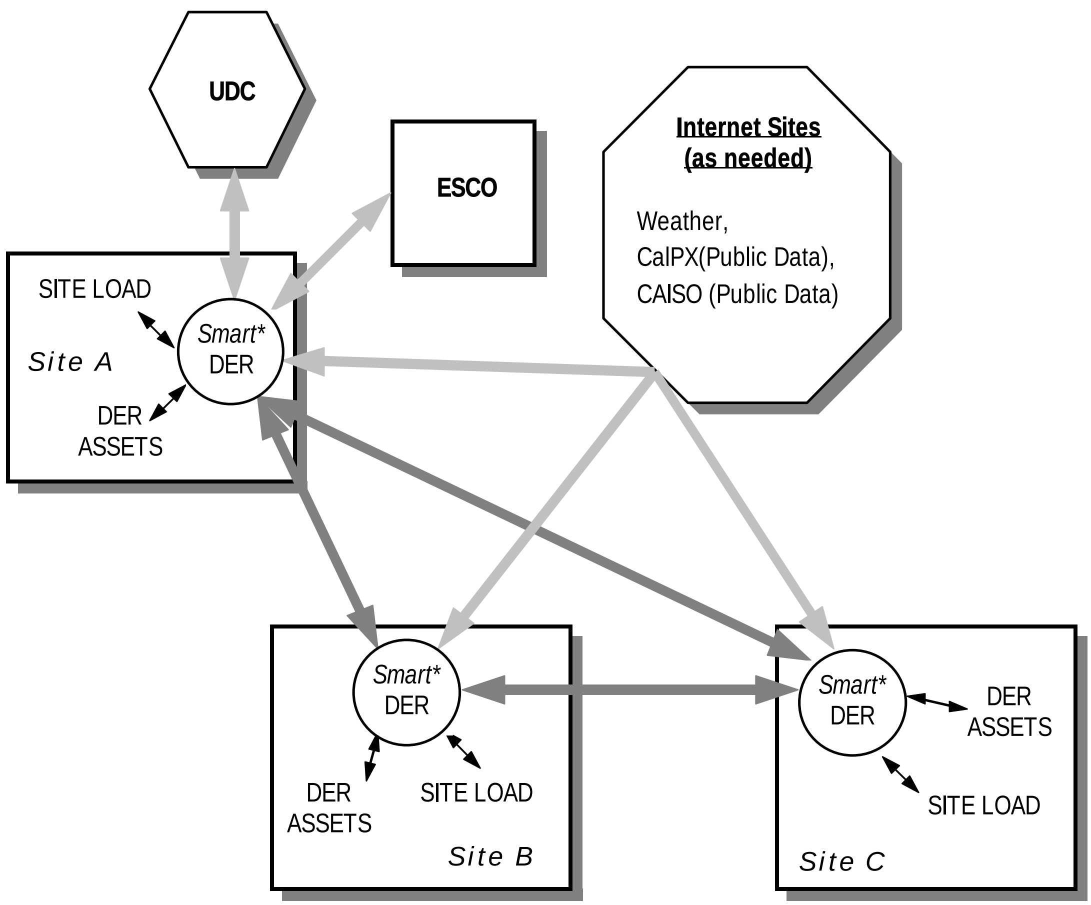


Figure 3. Multiple Sites – No Market Participation

The *Smart**DER agents at each individual site would have knowledge of site load and DER asset performance and would "represent" its site's interests in responding to UDC pricing signals (if provided) or ESCO load shaping constraints. As with the single site operating scenario, *Smart**DER agents could access the Internet for weather and possibly for electricity and natural gas prices depending on the DER asset involved. In this scenario *Smart**DER operates to reduce site energy costs but with the added complexity of operating in conjunction with other *Smart**DER equipped sites. In this scenario there is no direct involvement with external competitive markets.

The third operating scenario involves both aggregation of multiple assets and participation in one or more of the competitive markets. This operating scenario (Figure 4) is similar to the second scenario in that multiple sites are involved. However, in this case *Smart**DER agents are responding to, and participating in, one or more of the competitive markets operated by either the California Power Exchange (CalPX) or the California Independent System Operator (CAISO). Market participation could be either via the CalPX or another Scheduling Coordinator (SC). In this scenario, the *Smart**DER agents would have to balance site loads and costs against the potential return of bidding into one or more of the competitive markets. For instance, if high ancillary service pricing is predicted then bidding of standby generator capacity or curtailable load(s) could be justified.

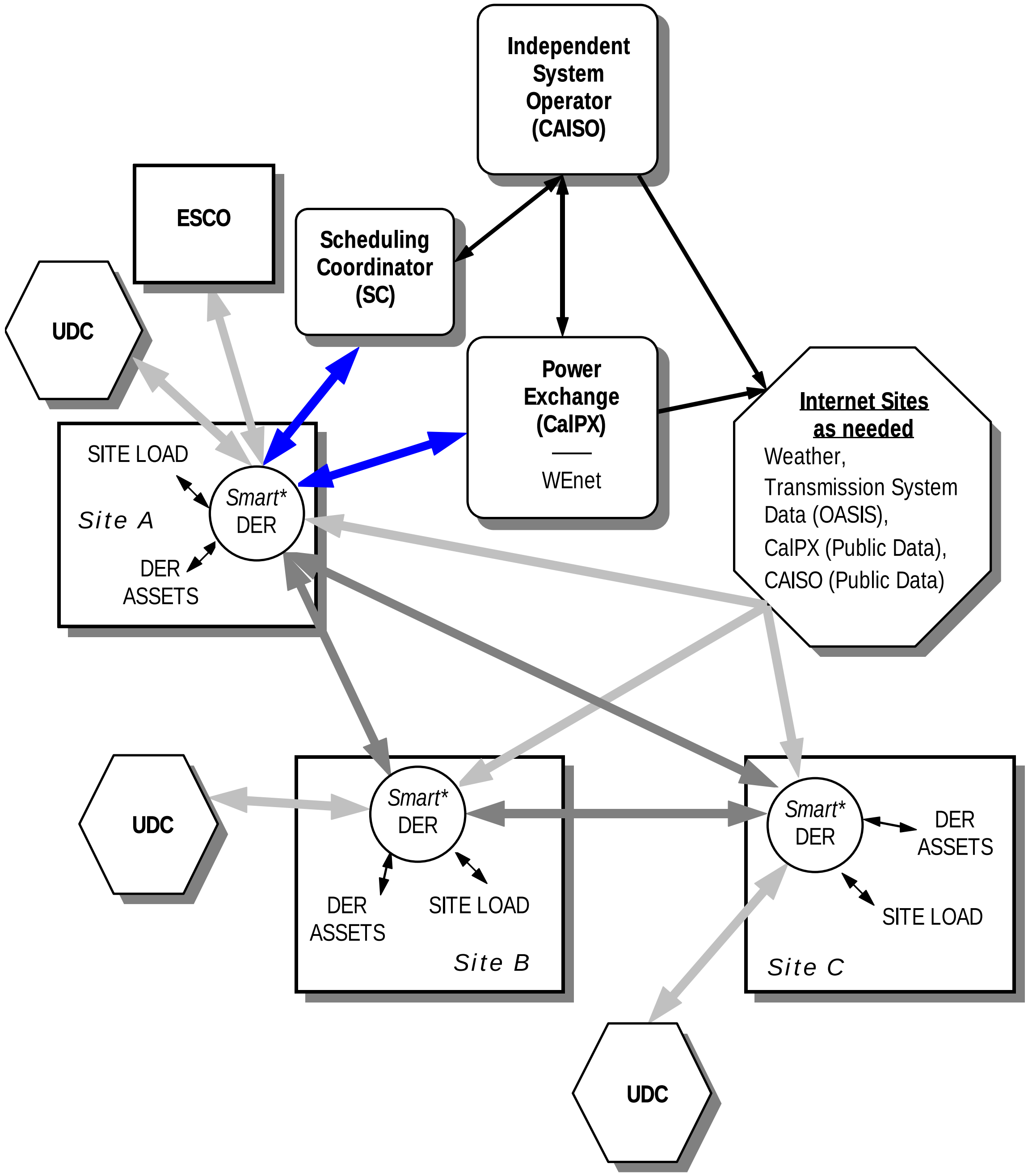


Figure 4. Multiple Sites – Direct Market Participation

The market participant group identified the first two operating scenarios as the most likely to occur in the near-term and intermediate-terms. Although in both cases, UDC involvement in the form of ownership or operation of DER assets is uncertain. While *Smart**DER could enable direct involvement in California energy and demand markets (operating scenario 3) this is seen as unlikely in the near-term. This type of involvement is seen as a more long term operating scenario as the California market continues to evolve and DER integration into the California marketplace progresses.

Based on the three basic operating scenarios and the potential DER assets involved we have identified the most likely *Smart**DER capabilities, which can be divided into two basic categories. The first category contains essential capabilities and the second contains capabilities that could improve product performance or market acceptance (e.g., bells and whistles). The seven basic capabilities considered essential to *Smart**DER product viability are:

- Monitor and Forecast DER Asset Performance/Output
- Monitor and Forecast Site Load (energy and demand) Requirements
- Monitor and Forecast Relevant Market Pricing
- Schedule DER Operation to Maximize Economic Benefit
- Graphical User Interface (GUI)
- Data Storage & Retrieval
- Communicate with External Entities (i.e., Internet, DER controls, etc.)

2.1.1.1 Virtual Evaluation Group

One of the primary objectives of the market research effort was to identify and engage key market participants in a "Virtual Evaluation Group". This group of individuals would then provide valuable feedback throughout the course of the project. During the market research effort, we were successful in assembling a diverse market participant group consisting of knowledgeable individuals that were well suited to providing the desired feedback.

Overall, the market participant group agreed with our description of the California electric market(s). Panel members understood the intelligent agent concept and confirmed the need for new scheduling and dispatch technologies. These technologies are necessary to facilitate widespread DER operation and grid integration. The market participants agreed with our initial assessment of how *Smart**DER agents could be integrated into the California marketplace but indicated that we were overly focused on the bulk power and ancillary services markets. We subsequently made changes to provide for *Smart**DER management of curtailable loads in response to either interruptible electric rates and/or the ancillary services markets. In addition, we now recognize the importance of *Smart**DER operation at an individual site to directly offset facility utility costs without any need for involvement in either the bulk power or ancillary services markets.

A Virtual Evaluation Group consisting of individuals that participated in our market participant group was formed (Appendix III). We had initially envisioned a relatively large base of market participants from which to choose. What we found was that market participants that had provided comments did so because they had both an interest and desire to participate throughout the project. For this reason, the Virtual Evaluation Group was comprised of all of the market participants that provided comments/feedback.

2.1.1.2 Identify Potential Commercialization Partners

It would have been premature to negotiate with, or otherwise engage, a commercial partner given the early stage of our project. However, we were able to identify the commercial partner traits that will maximize the benefit to the *Smart**DER development and commercialization efforts. These traits call for a commercial partner that has:

- An existing product or technology that enhances potential Smart*DER market penetration,
- An existing product distribution / support infrastructure, and
- Industry Name / Trademark Recognition

In addition, we were able to identify potential commercialization partners having some or all of these traits. Some of these potential partners agreed to participate in the evaluation group. Other partners will be more approachable as the Smart*DER product development process progresses.

2.2 Task *2 Smart**DER Agency Development and Testing

Development of the *Smart**DER agency and its individual agents was the goal of this project task. This effort was broken down into nine subtasks. The development effort began with tasks devoted to defining the *Smart**DER agency and its agents and progressed to testing of the individual agents and then the agency as a whole. The nine subtasks that comprised this task are briefly described in the following subsections. A critical project review was conducted during this effort so the following descriptions and deliverables are summarized prior to and following the critical project review.

2.2.1 DER*S Task Analysis and Characterization

The purpose of this task was to clearly describe the functional requirements of each agent as well as the overall agency based on the product requirements developed during the domain analysis and market research efforts.

2.2.2 DER*S Agency/Agent Specification

The purpose of this task was to prepare a detailed product specification that could be used as the basis for the remaining development activities. In addition to the overall product specification, the product specification also contained the requirements associated with the individual agents.

2.2.3 Ontology Development

The purpose of this task was to identify the major components of the energy industry ontology as it relates to the application of distributed energy resources. Ontology is a formal description of a problem domain that gives meaning to the symbols and expressions used to describe a domain. For one agent to properly understand the meaning of a message from another agent, both agents must ascribe the same meaning to the symbols (constants) used in that message. In other words, a network of agents uses the ontology to make sure they are comparing apples with apples.

2.2.4 Algorithm and Tool Research

The purpose of this task was to determine the software tools and algorithms that are needed to support *Smart**DER technology. In some cases tools or algorithms already existed while in other cases it would be necessary to develop algorithms based on each agents needs. As part of this effort we developed an agent technology matrix that detailed the needs as well as candidate algorithms.

2.2.5 Algorithm Development and Testing

The purpose of this task was to develop algorithms identified in the previous subtask and to test and evaluate these algorithms to identify the most promising tools and algorithms for each of the agents.

AESC provided the following deliverables prior to the second critical project review as part of first five subtasks of the Task 2 effort:

- Preliminary Agency Specification
- DER*S Specification Report
- Ontology Report
- Algorithm Research Report
- Algorithm Development and Testing Report

The Commission Contract Manager conducted the second Critical Project Review at the conclusion of this subtask.

2.2.6 Agent Software Module Development and Testing

The purpose of this task was to develop and test the individual agents and supporting software modules that were identified in the previous subtask. As part of this effort we designed, developed and tested software modules that provided the agent functionality identified previously. These software modules are known as the Private Accessory Classes (PAC) of intelligent agents. PACs were developed and tested for each agent.

2.2.7 Agency Construction

The purpose of this task was to construct the *Smart**DER agency and conduct basic agency testing to prepare for integration of the PAC software developed and tested in the previous subtask.

2.2.8 Integration of PAC Software

The purpose of this task was to integrate the PAC software into the *Smart**DER agency. At the end of this task a fully functional *Smart**DER agency would be ready for further testing.

2.2.9 Agent and Agency Testing

The purpose of this task was to extensively test the *Smart**DER agency prior to fully integrating and testing in the simulated operating environment (EASE) that was being developed concurrently under Task 4.

AESC provided the following deliverables prior to completion of the Task 2 effort (following the second critical project review):

- Report describing the PAC software.
- Preliminary EnerAgent™ test report.
- DER*S Test Report (included in the Task 4, Final DER*S Test Report deliverable)

2.2.10 Task 2 Results

During Task 1 we defined the basic *Smart**DER product operating scenarios, requirements, and capabilities. In this Task 2 effort we proceeded to define the various agents that would be needed within a *Smart**DER agency and then developed and tested these agents. Initially we concentrated on analyzing and characterizing the various tasks associated with *Smart**DER operation. This resulted in the seven agent *Smart**DER agency depicted in Figure 5 and described in detail in the following sections (see also DER*S Preliminary Agency Design Report).

Communication between agents is Internet-based and utilizes TCP / IP protocols. While it is not evident from the figure, which appears to depict all of the agents in close proximity to one another, agents may actually be located on multiple machines. Use of web-based communications as well as JAVA based code facilitates the use of multiple platforms. For example, the Data Manager agent shown on the figure could easily reside on a server located in the information systems or data processing center while the owner interface agent could be located on a PC in the facilities management area. Likewise the Facility Interface Agent could be running on the same PC that communicates with building energy management system software.

2.2.10.1 *Smart**DER Agency Review

*Smart**DER™ technology operates to schedule the operation of one or more DER assets at a single or multiple sites. *Smart**DER agencies utilize intelligent agent technology to distribute the decision-making and data processing workload among multiple agents. Each agent operates independently yet collaborates with other agents to achieve the overall scheduling objective. Just as an individual *Smart**DER agency consists of multiple agents, multiple *Smart**DER agencies (each assigned to a specific DER equipped site) can operate independently yet cooperatively to coordinate activities at multiple sites.

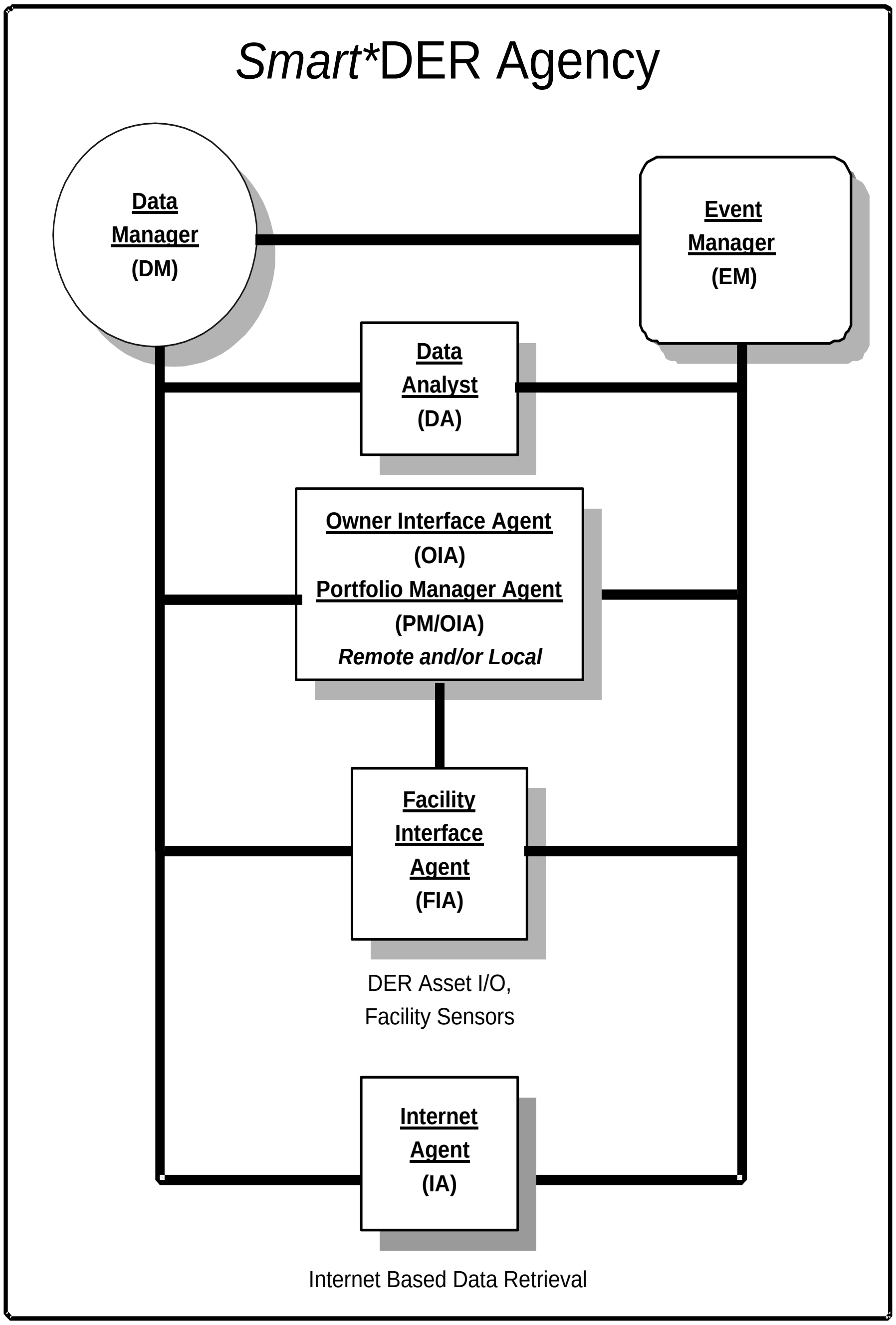


Figure 5. *SmartDER™ Agency Diagram**

2.2.10.2 Agent Descriptions

The following sections, organized by agent, summarize the functionality of each individual agent that was developed and tested during the project.

Owner Interface Agent (OIA)

The Owner Interface Agent (OIA) is devoted to communication between the Smart*DER agency and the owner/user. The primary feature of the OIA is its graphical user interface (GUI), which facilitates user input (manual overrides, site set-up, etc.) and review of Smart*DER information. All Smart*DER equipped sites have an OIA located at the site that communicates directly with the remaining Smart*DER agents directly using protocols provided by the AgentBuilder® development system.

Portfolio Manager (PM)

In some operating scenarios a portfolio of *Smart**DER equipped sites may cooperate in order to participate in either the energy (CalPX) or ancillary services markets (AS). In these situations a single OIA is designated as the market manager and is provided with additional functionality. The portfolio manager OIA (PM/OIA) aggregates portfolio assets through an auction process and communicates with the marketplace on behalf of the portfolio. The PM/OIA may be located at one of the portfolio sites or may be remotely located at the offices of a third party owner/operator.

Event Manager (EM)

The Event Manager (EM) is responsible for accomplishing periodic *Smart**DER agency activities. The EM monitors system time and requests action by other *Smart**DER agents to accomplish the needed activity. Examples of routine *Smart**DER functions include DER operating schedule updates and weather data collection. During agency start-up the EM reads the *Smart**DER set-up data provided by the DM and initializes *Smart**DER scheduled activities. The EM subsequently acts independently from all other agents to accomplish the scheduled activities.

Data Manager (DM)

The Data Manager (DM) agent is the central repository for all *Smart**DER data and provides data archiving and retrieval services for the *Smart**DER agency. The DM responds to requests from any *Smart**DER agent that requires data. DM functionality is limited to data storage and retrieval as well as examination of stored data to determine its suitability relative to the data request. The DM works via the Facility Interface Agent (FIA) to access facility and DER sensor information and uses the Internet Agent (IA) to obtain data that are external to *Smart**DER (i.e., weather data, transmission availability, relevant pricing data, etc.). The DM may also request that the DA generate new operating schedules and or predicted pricing information if stored schedules and information do not meet the needs of the requesting agent.

Facility Interface Agent (FIA)

The Facility Interface Agent (FIA) serves as the *Smart**DER agency connection to all of the facility sensors as well as the DER asset sensors and associated controls. The FIA routinely accesses the site sensor (including DER asset sensors) using existing facility communication networks and provides 15-minute data to the Data Manager for storage. In addition, the FIA transmits operating commands to the DER asset in response to Event Manager requests. The FIA communicates primarily with the Data Manager and Event Manager agents. FIA functionality is limited to data conversion, transmittal and receipt of data from facility and DER asset sensors. Note that the FIA accesses text files for data that would normally come from facility / DER sensors for testing and demonstration software purposes.

Internet Agent

The Internet Agent (IA) serves as the DER*S agency's connection to all Internet-based information sources. The IA responds to requests for information retrieval or transmittal and accesses the necessary Internet sites. The IA communicates almost exclusively with the Data Manager for retrieval of information and with the Event Manager for information transmittal (CalPX / SC, if needed).

Note that the *Smart**DER demonstration software retrieves market pricing, system load and weather data from a "pseudo" web site maintained by Reticular Systems. This will enable AESC to track use of the demonstration software.

Data Analyst

As the name implies, the Data Analyst (DA) agent provides data analysis in support of *Smart**DER operation. DA analysis activities include:

- Prediction of site electric and thermal (if applicable) load,
- Prediction of relevant pricing (energy, ancillary services, fuel, etc.),
- Generation of beneficial operating schedules for the various DER assets at a given site,
- Preparation of reports summarizing site or portfolio activities, and
- Analysis support for PM / OIA coordination of *Smart**DER actions between multiple sites.

The DA agent operates in response to analysis requests coming from the DM. In this way, the DM serves as the central repository for all analysis results. Note that prediction algorithms, while investigated, were not implemented during the PIER project since prediction capabilities are not essential to accomplishing the primary project objective of demonstrating the viability of the intelligent agent concept. In addition, we felt that *Smart**DER operation using predicted load and price information would insert a level of uncertainty that could be counterproductive.

2.2.10.3 *Smart**DER Agent Testing

During the course of development AESC personnel confirmed individual agent operation and functionality. In addition, AESC confirmed all of the agent-agent communications associated with normal operation. Results of these testing efforts were summarized in the Final DER*S Test Report.

2.3 Task 3 EASE Development and Testing

The purpose of this task was to develop and test the simulation environment (EASE) needed to test the *Smart**DER agencies in a realistic operating environment. The general goal was to develop EASE so as to allow the objective evaluation of the *Smart**DER agencies. This research and development effort was comprised of three subtasks.

2.3.1 Development of Detailed EASE Requirements

The purpose of this task was to develop the detailed EASE requirements. AESC's principal subcontractor, Reticular Systems, Inc. (Reticular), summarized these requirements in the EASE System Product Specification. This document also summarized the EASE Test Plan, which described the test plans, procedures and methods.

The Commission Contract Manager conducted the second Critical Project Review at the conclusion of this subtask (coincided with completion of Algorithm Development and Testing subtask of Task 2)

2.3.2 Create Comprehensive EASE Software Design

The purpose of this task was to design the EASE software and summarize the basic design in a Preliminary EASE Software Design Report.

2.3.3 Construct and Test EASE Software

The purpose of this task was to construct and test the EASE software in preparation for integration and testing with the *Smart**DER agencies that were also under development (Task 2). Reticular updated and submitted a Final EASE Software Design Report at the conclusion of this subtask.

AESC and its principal subcontractor, Reticular Systems, Inc. provided the following deliverables prior to completion of the Task 3 effort:

- EASE System Product Specification and Test Plan (provided prior to second critical project review)
- Preliminary EASE Software Design Report
- Final EASE Software Design Report

2.3.4 Task 3 Results

This project task effort was primarily the responsibility of Reticular Systems and occurred concurrently with the DER*S Development and Testing effort. As described previously, EASE is the EnerAgent Simulation Environment, which allows for realistic operation / testing of *Smart**DER agencies. Early efforts were focused on defining EASE functional requirements, which were summarized in the EASE Product Specification Report. These requirements were refined and the final EASE software design, which was developed and tested, is briefly summarized in the following sections (refer to the Final EASE Software Design Report for additional information).

2.3.5 EASE Description

EASE consists of several different components, the first of which is a *Smart**DER agency configuration tool. This is a standalone GUI application used for installing and configuring a *Smart**DER agency. The second component consists of a web server that emulates the various web-based entities that a *Smart**DER agency communicates with during normal operation. A third EASE component is a simulation control agent, which is used to monitor and control a simulation run for one or more *Smart**DER agencies. EASE simulation control includes a graphical user interface for control and monitoring of the simulation as well as multiple software components that are integrated directly into the *Smart**DER agents.

***Smart**DER Agency Configuration Tool Capabilities**

EASE provides a *Smart**DER Agency Configuration tool that is used for installing and configuring individual *Smart**DER agencies. *Smart**DER agents are able to run on separate computers and communicate across networks or the Internet to perform the tasks of a single *Smart**DER agency. In order to simplify the installation, configuration, and monitoring of the demonstration system, the *Smart**DER agency configuration tool installs all the agents for a single *Smart**DER agency onto a single computer. Using the configuration tool, multiple agencies can be installed on multiple computers to simulate operation of a distributed asset portfolio.

*Smart**DER agencies are self-configuring in that agents initiate communications with one another automatically. Therefore, agency configuration is relatively simple in that its sole function is to create a property file used by all of the agents. This property file provides enough information for the various agents to discover each other and begin communicating. The *Smart**DER agency has been designed such that the Data Manager (DM) agent is the central source of information. Therefore, each agent uses information from the property file to discover the location of the relevant DM agent. As the agents register with the DM they discover the locations of other agents within the agency thus enabling communication between all of the agents.

Participation in one the energy or ancillary services markets is the responsibility of the Portfolio Manager agent (PM / OIA). If market participation is not required (i.e., DER assets are used exclusively for local bill reduction) then there is no need for a PM / OIA. A single PM / OIA coordinates the actions of multiple agencies (a portfolio of agencies) via communications with the Owner Interface Agent (OIA) of each *Smart**DER agency. To enable market participation the property file contains information on market participation and, if needed, the location of the single PM / OIA. When market participation is required, the OIA of each of the agencies within a portfolio of *Smart**DER equipped sites uses the information in the property file to locate the PM / OIA and initiate communications. For testing and demonstration purposes the property file also contains the location of the EASE simulation control, which provides timebase and execution control capabilities for all agents operating in any of the participating *Smart**DER agencies.

The *Smart**DER agency configuration tool is a standalone graphical user interface (GUI) used for creating the properties file. A sample screenshot of the GUI is shown in Figure 6. In this screenshot, Market Participation has been selected without Local Portfolio Manager. These selections indicate that the site will participate in the energy or ancillary services markets but the PM / OIA is not located at this site. This combination of selections will notify the site OIA that it needs to contact the PM / OIA to initiate market participation activities. Thus the PM / OIA does not need to have any prior knowledge that a site will participate in portfolio activities and the process of adding sites and assets to the portfolio is simplified.

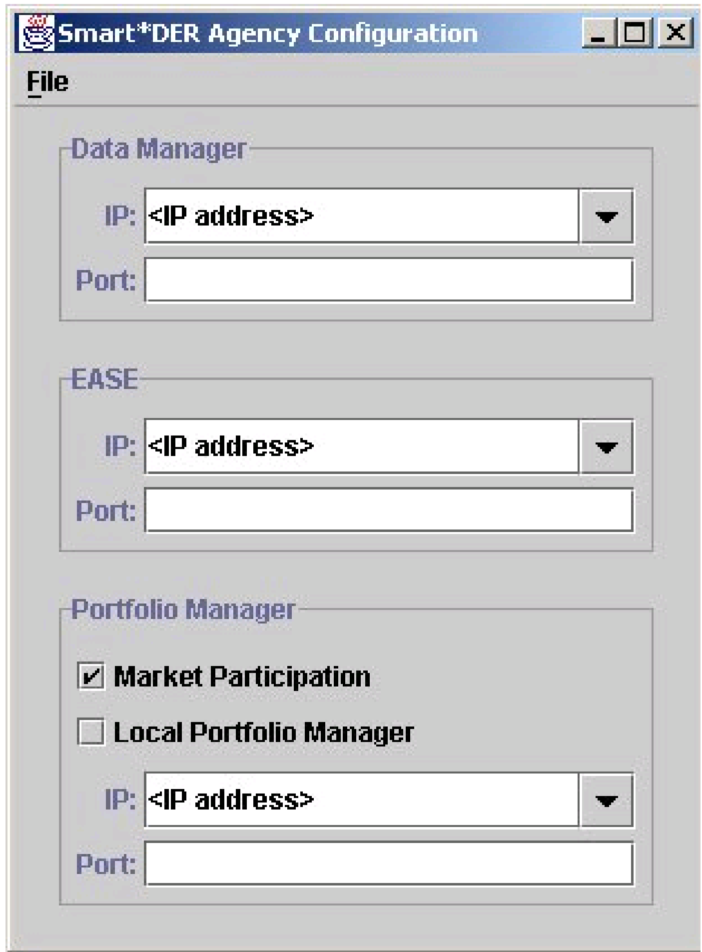


Figure 6. EASE Configuration Tool Input Screen

<u>EASE Web Emulation Services</u>

The EASE web server is hosted by Reticular Systems and provides emulation services for the external entities that a *Smart**DER agency communicates with during normal operation. The EASE web server provides two basic services.

<u>Data Retrieval</u> - The *Smart**DER agency requires pricing and weather information to develop cost effective operating schedules for the various DER assets. In a commercial environment the Internet Agent (IA) would obtain this information on a daily basis from websites maintained by the CalPX and CAISO (pricing) and from a commercial weather data website. Providing these services on a consolidated web server ensures availability of these resources during testing and demonstration of *Smart**DER agencies. The EASE

web server mimics the weather, CalPX and CAISO web sites using 1999 historical data for the San Diego region. Use of historical data provides a controlled and known environment for *Smart**DER testing and demonstration. The web server provides:

Auction Interaction - When market participation is desired it is the responsibility of the PM / OIA to represent one or more *Smart**DER equipped sites in both the CalPX (day-ahead energy spot market) and CAISO (ancillary services) markets. The EASE web server emulates this interaction by accepting, processing and returning auction results to the PM / OIA via the Internet Agent. These actions are handled via a servelet on the EASE web server. Note that no attempt was made to emulate the CAISO and CalPX auction protocols since *Smart**DER would not communicate directly with these entities in a commercial environment but would instead communicate via a Schedule Coordinator.

EASE Simulation Control

EASE control of a *Smart**DER simulation run is accomplished using a separate EASE agent with a graphical user interface (GUI). The various parameters for a simulation that are controlled with this GUI include:

- 1999 Date for Simulation,
- Time base acceleration constant for running the simulations faster than real-time,
- Probability of Ancillary Services (Non-Spinning and Replacement Reserves) capacity being called during the simulation, and
- Simulation start / stop control.

The EASE simulation control agent monitors and communicates with *Smart**DER agents across all agencies during a simulation run. One of the main functions of this agent will be to generate CAISO requests for Ancillary Services (AS) capacity during a simulation run. These requests are communicated directly to the PM / OIA for action.

***Smart**DER Test Bed Capabilities**

Other interactions between *Smart**DER agents and EASE are accomplished with Personal Action Classes (PACs) that are incorporated into each *Smart**DER agent. The following sections briefly summarize the interaction that each *Smart**DER agent has with EASE, via these PACs during a simulation run.

Common Agent Capabilities - Time Base Control - EASE provides a time base control PAC that is integrated into each *Smart**DER agent. Two types of time control are required. First, the user needs a mechanism for setting the current time to an arbitrary value, which allows simulations to be performed for defined timeframes independent of the current wall clock time. This ability is especially useful when simulations are run using historical data. Second, control of simulation speed is required to allow extended timeframe simulations to be performed faster than real-time. In a real word environment, the time base PAC can be easily swapped out with one that provides a simple pass through of wall clock time. The EASE simulation control agent and GUI are used to communicate with the time base control PACs contained in each *Smart**DER agent. Note that the *Smart**DER agency is the first AgentBuilder agency to incorporate continuous simulation time and timer functionality across multiple agents under control of a single GUI.

Agent Specific Capabilities - As noted previously, EASE emulates the environment that a *Smart**DER agency would encounter during normal operation. As autonomous entities, each *Smart**DER agent interacts with this environment individually and as such EASE must accommodate the needs of each agent. Table 1 summarizes the agent specific interaction.

Table 1. EASE Agent Specific Capabilities

Agent	EASE Capabilities
Owner Interface Agent (OIA)	EASE does not interact directly with the OIA but instead generates OIA activity via responses to data that EASE initially supplies to other *Smart**DER agents (i.e., weather data, etc.), which results in actions and communications that involve the OIA.
Portfolio Manager (PM/OIA)	EASE interacts with the PM/OIA to emulate: 1) the interaction associated with participation in the CalPX and CAISO auctions and 2) the CAISO call for ancillary services capacity.
Event Manager (EM)	There are no EASE components specific to the EM agent, however the EM relies heavily on the EASE time base functionality described previously.
Data Manager (DM)	The EASE simulation control agent uses the data supplied by each DM: 1) for monitoring and logging of activities/events associated with simulation runs, 2) to display agency configuration information for the simulation user.
Facility Interface Agent (FIA)	A special purpose EASE PAC provides site sensor and DER operating parameters to the FIA on one minute simulated time intervals using template files installed with each agency by the configuration tool control. A second PAC interprets the schedule commands sent by the EM to the FIA and modifies the sensor data accordingly (i.e., change a kW reading if a generator is turned on, etc.).
Internet Agent (IA)	The EASE web server emulates the CalPX and CAISO and responds to IA requests for information and provides auction support. The EASE web server also provides weather data upon request.
Data Analyst (DA)	The DA makes extensive use of data provided by EASE via other *Smart**DER agents (FIA, IA) but does not have any EASE components specific to the DA agent itself.

2.4 Task 4 DER*S – EASE Integration and Testing

The purpose of this task was to integrate the previously developed *Smart**DER agency with EASE. The purpose of this integration and subsequent testing was to verify that EASE and *Smart**DER agency protocols are compatible. During this effort it was necessary to modify EASE, and various *Smart**DER agents. Testing of fully integrated system in both single and multiple site (multiple agency) configurations was conducted. Results of this testing effort was summarized in the DER*S Final Integration Test Report.

As part of this effort, AESC also provided a demonstration of *Smart**DER agent technology for members of the Virtual Evaluation Group of market participants so that their feedback could also be included in the Final Integration Report.

AESC and its principal subcontractor, Reticular Systems, Inc. provided the following deliverables prior to completion of the Task 4 effort:

- DER*S Final Integration Test Report
- Demonstration of the Integrated Package

2.4.1 Task 4 Results

As noted above, EASE enables realistic operation / testing of the *Smart**DER agents / agency by providing software simulation of real-world resources and assets (sensors, generators, etc.) as well as emulation of communications between *Smart**DER and external entities (weather services, CalPX / CAISO, etc.). In addition, EASE provides services specific to the simulation environment including configuration assistance in setting up a *Smart**DER agency and time base control for performing simulations faster than real-time. Once the agent software is installed, operation of a *Smart**DER simulation / test is a three step process where the:

- Simulation environment is established and then initiated using EASE (EnerAgent Simulation Environment),
- Simulation progress is observed using screens provided in EASE, the Site OIA and the Portfolio Manager GUIs, and
- Final results, in the form of DER schedules and associated financial and operations information, are summarized in reports provided in both the Site OIA and Portfolio Manager GUIs.

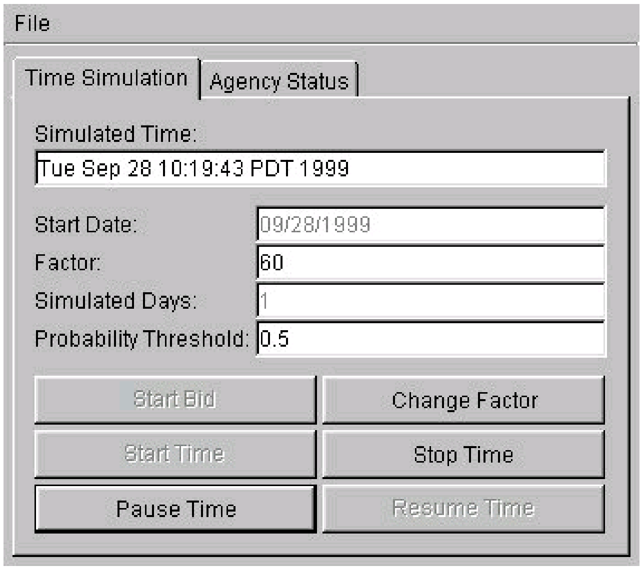
2.4.1.1 Simulation Setup

EASE provides the *Smart**DER agents with an operating environment that:

- Emulates the external entities (CAISO, CalPX, etc.) that a *Smart**DER agency would communicate with,
- Allows selection of a test day,
- Provides for time base control (i.e., accelerated system operation, starting / pausing / stopping a simulation), and
- Displays information on agent status during execution.

The EASE GUI consists of two screens, which are shown in Figure 7. The first screen provides for test date selection, and specification of time base acceleration “Factor”. In addition, the user can start, pause / resume and stop the simulation using buttons located on this screen. In addition, the user may specify a “Probability Threshold”, which is the probability that the CAISO will call for any capacity that was successfully bid into one of the ancillary services markets. The second screen displays the status of each agent in any agency that is participating in the simulation.

Simulation results consist of the DER schedules and associated savings. Individual site results are observed using screens provided in the Site OIA GUI, while multiple site or portfolio results are observed using displays associated with an individual site or income and expense that result.



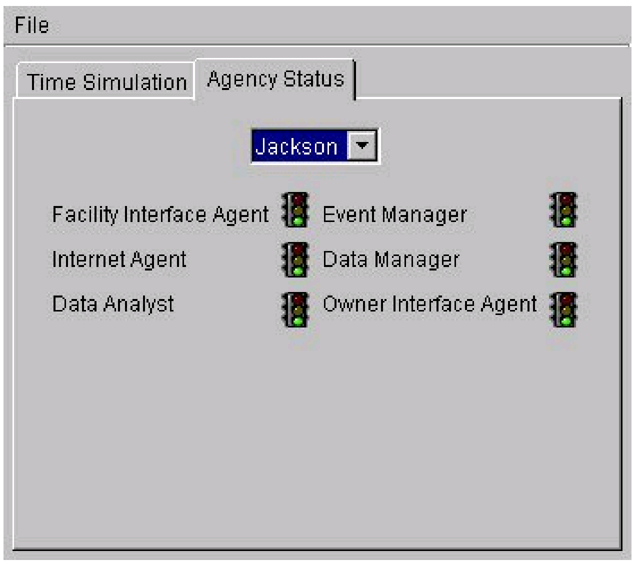


Figure 7. EASE User Interface Screens

2.4.1.2 Operating Environment

Testing was conducted on a variety of platforms and operating systems. During the course of development *Smart**DER agents / agencies were run on personal computers under the Windows ME, Windows NT and Windows 98 operating systems as well as computers[3] operating the Solaris operating system.

2.4.1.3 Test Description

Testing was conducted to confirm *Smart**DER operation in a variety of configurations and with a number of different test days. As noted previously, test days were confined to the 1999 calendar year. Testing confirmed that the *Smart**DER agencies successfully scheduled the operation of the DER assets involved. Two of the basic test cases, one case for a single site having multiple assets and a second case with two sites, each with multiple assets are presented in the following subsections. The single site test case will be described for September 27, 1999 and the dual site test case will be illustrated under operating conditions that existed on September 28, 1999. These dates were selected in order to illustrate both bidding into and subsequently providing capacity into the California energy markets.

For testing purposes, we assumed that *Smart**DER operation would provide DER operation to:

- Reduce site utility energy costs
- Participate in the CalPX energy auction,
- Participate in the Day Ahead CAISO Non-Spinning and Replacement Reserve ancillary services (AS) markets,

Furthermore, in order to enhance site participation in the various markets we used a minimum bid size requirement of only 10 kW compared with the actual 1 MW requirement used by the CAISO. In addition, we assumed that a bid into the CAISO AS markets would be accepted as long as it occurred on a weekday between the hours of 10 a.m. and 8 p.m. The probability of subsequently providing AS capacity that was successfully bid in any given hour was set for 0.5.

2.4.1.4 Site Descriptions

Weather, market pricing and building load profile information was confined to the San Diego area so all tests were conducted for sites located in the San Diego area. Fuel (natural gas) prices were taken from 1999 EIA data for California.

Single site test cases were run using a site with the following characteristics:

- Large commercial load profile,

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[3] Operation on Unix based machines did not include the Data Manager agent, which uses the Microsoft Access DB and is therefore limited at this time to Windows based machines.

- Peak annual demand of 300 kW,
- SDG&E Time of Use electric rate tariff for secondary distribution customers (AL-TOU Secondary),
- DER assets consisting of a natural gas fueled 200 kW recuperated gas turbine with a nominal electric efficiency of 42 percent and a second 200 kW reciprocating type generator with a nominal efficiency of 35 percent.

For test cases where a second site participated, a test site was added with the following characteristics:

- Small commercial load profile,
- Peak annual demand of 150 kW,
- SDG&E Time of Use electric tariff for secondary distribution customers (AL-TOU Secondary),
- DER assets consisting of a natural gas fueled 100 kW reciprocating type generator with a nominal electric efficiency of 35 percent and a second 75 kW reciprocating type generator with a nominal efficiency of 33 percent.

2.4.1.5 Test Day Market Prices

Ancillary services and unconstrained market clearing price (UMCP) data are shown in Figures 3 through 6 for the two test days, September 27th and September 28th, 1999. These two days were selected based on the variety of pricing that was evident. On the 27th the Non-Spinning Reserve AS market pricing was higher while on the 28th the Replacement Reserve market pricing provided the best opportunity. UMCP values also varied significantly for each day.

2.4.1.6 Test Results – *Smart**DER Operation

*Smart**DER operation is dynamic in the sense that multiple agents operate independently and communicate continuously with other agents within the *Smart**DER agency to accomplish the DER scheduling and dispatching functions. This dynamic agent/agency characteristic is difficult to illustrate in a report format. However, the fact that test results are offered for this and the dual site test cases indicates that *Smart**DER successfully:

- Operated multiple agents at one or more sites to achieve the *Smart**DER scheduling and dispatch functions,
- Established communications with the DER*S demonstration website to retrieve weather and pricing information and to interact with CalPX and CAISO auctions,
- Conducted an intrasite auction to establish a portfolio response to one or more of the California markets (CalPX, CAISO), and
- Implemented CAISO calls for capacity, when needed.

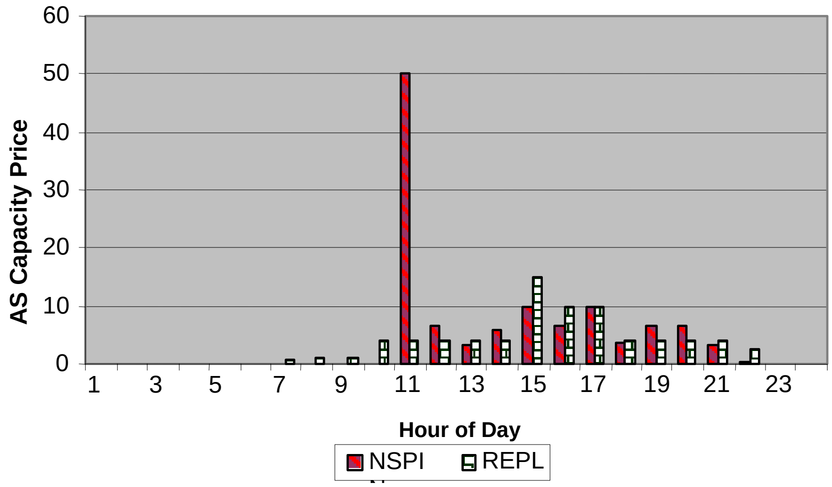

Figure 8. Ancillary Service Capacity Prices – 9/27/99

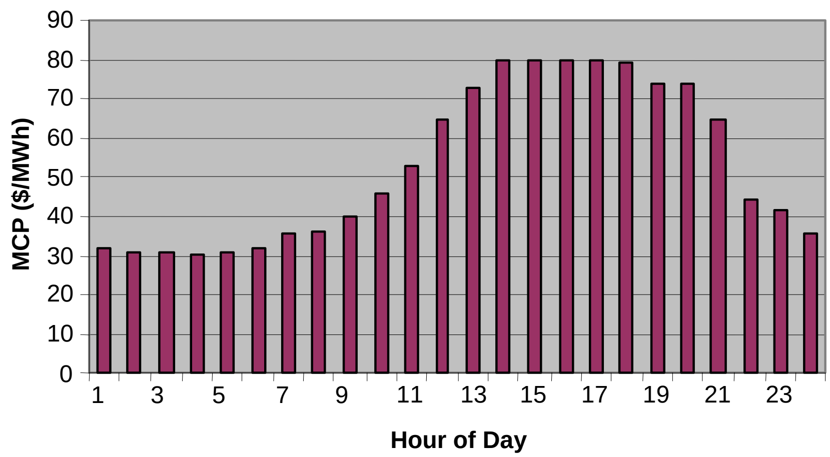

Figure 9. Unconstrained Market Clearing Price – 9/27/99

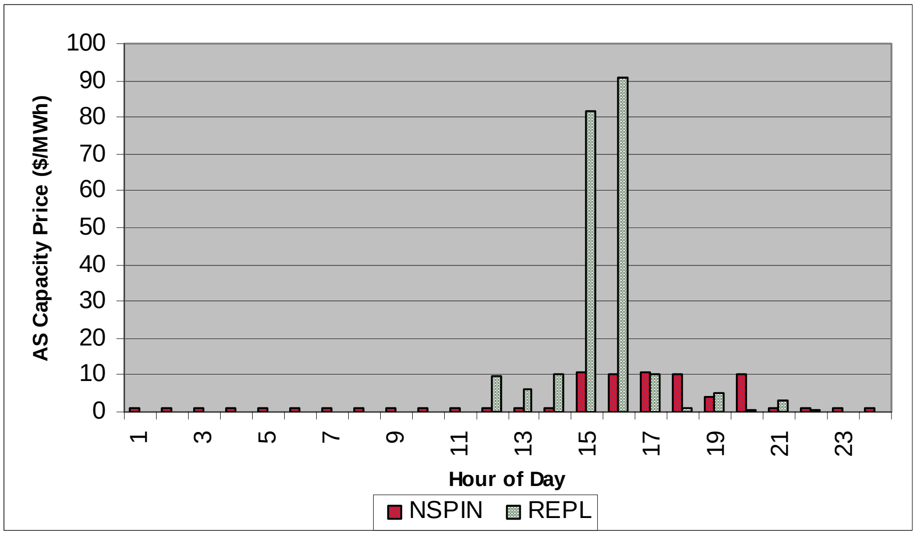

Figure 10. Ancillary Service Capacity Prices – 9/28/99

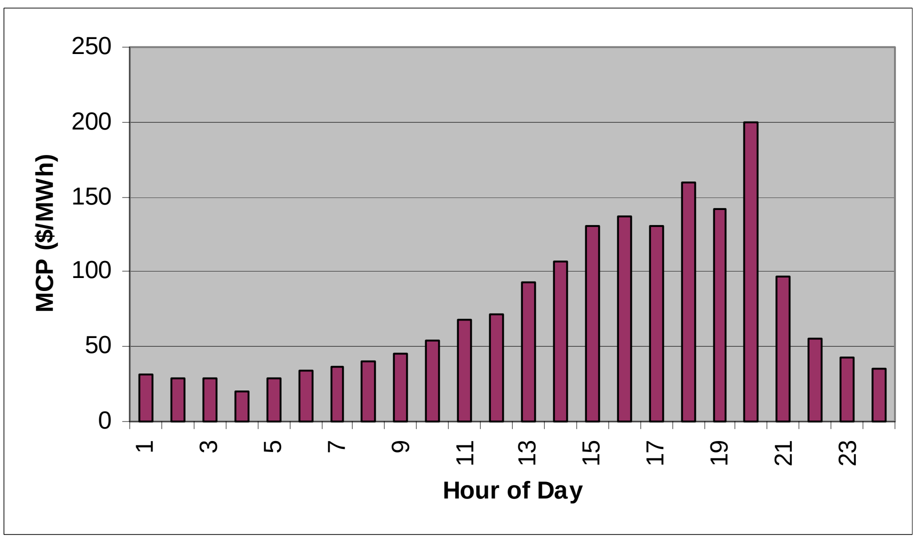

Figure 11. Unconstrained Market Clearing Price – 9/28/99

2.4.1.7 Test Results - Single Site, Multiple DER Assets

Results of *Smart**DER agency operation under operating conditions (weather, site load and pricing) that existed on September 27, 1999 are illustrated in the Site OIA screens show in Figures 12, 13 and 14. Figure 12 graphically depicts the DER operating schedule that was planned and subsequently implemented. The schedule shows continuous operation (shown as green) of the more efficient regenerative gas turbine to offset site load with operation of the less efficient reciprocating unit beginning at 10 a.m. to offset the midday peak and continuing until 4 p.m. (hour 16). In addition, *Smart**DER committed the remainder of the second asset's capacity to the AS market (shown as blue) to take advantage of the AS price spike (see previous Figure 8). *Smart**DER continued to commit all of the second asset's capacity to the AS market even after it ceased to operate to offset site load at 4 p.m.

The resulting site load (net demand after asset operation) is depicted in Figure 13. As the figure shows site load exceeded the capacity of the first generation asset after 5 a.m., which could have signaled a need to operate the second asset. Yet *Smart**DER did not schedule operation of the less efficient asset until 10 a.m. In this case, the operating costs (i.e., fuel and O&M costs) associated with part-load operation of the second asset exceeded the benefit associated with operation of the unit to offset site load. Operation could not be justified until higher energy prices, higher site load and the availability of income associated with the AS market provided sufficient additional income to justify unit operation at the later time. Note that this screen updates continuously during operation with green values depicting measured values and gold values showing predicted values. This particular screen shot was taken at 7:15 a.m. (simulated time).

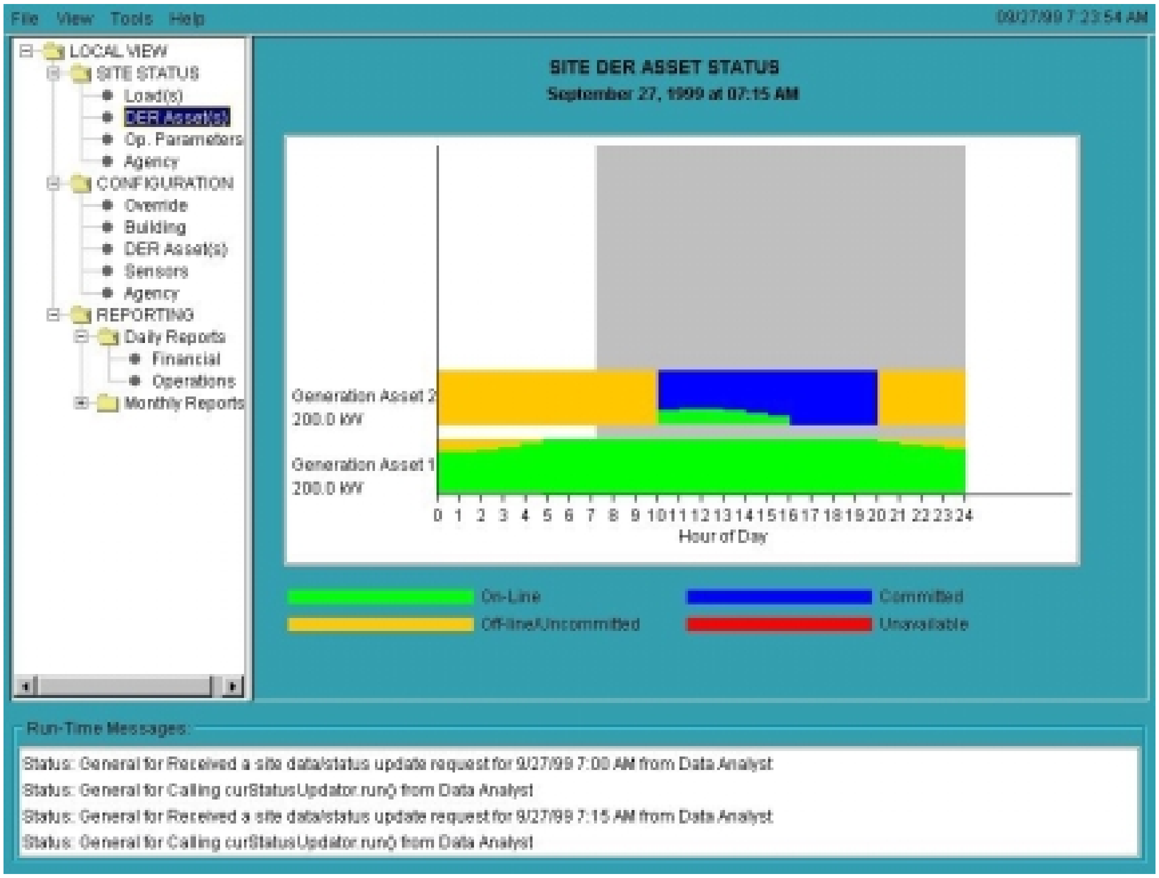

Figure 12. Single Site Operating Schedule for 9/27/99

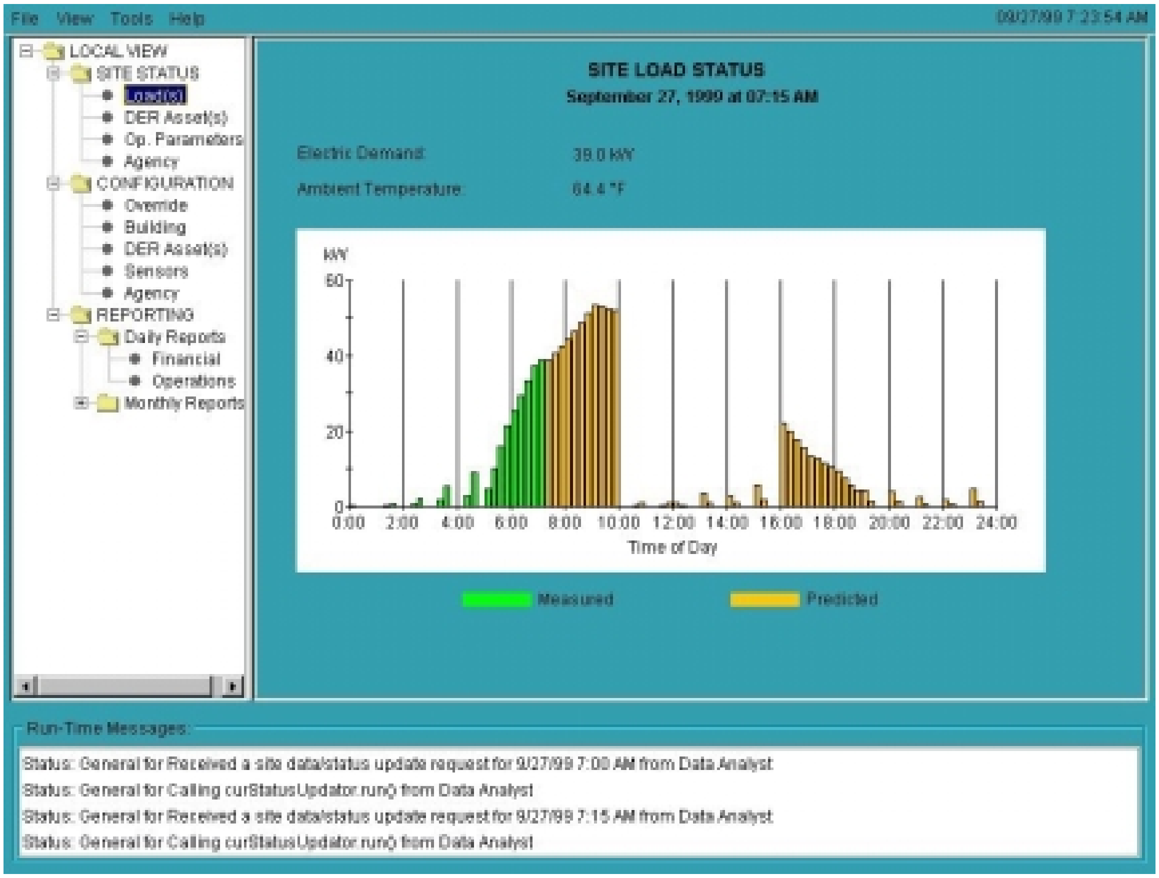

Figure 13. Single Site Load Status for 9/27/99

The economic results for operation of the single site on September 27th are shown in the OIA GUI, Site Daily DER Financial Summary screen depicted in Figure 14. From a financial perspective the additional income associated with participation in the AS market was modest. An additional $17.55 was obtained from the sale of the second asset's capacity and an additional $19.61 was obtained from the eventual sale of energy to the CAISO. Note that operation of the second asset in response to a CAISO call for capacity does not appear on the operating schedule previously shown in Figure 12 since the call for capacity occurred after the 7:15 a.m. snapshot of the OIA DER Status Screen was taken.

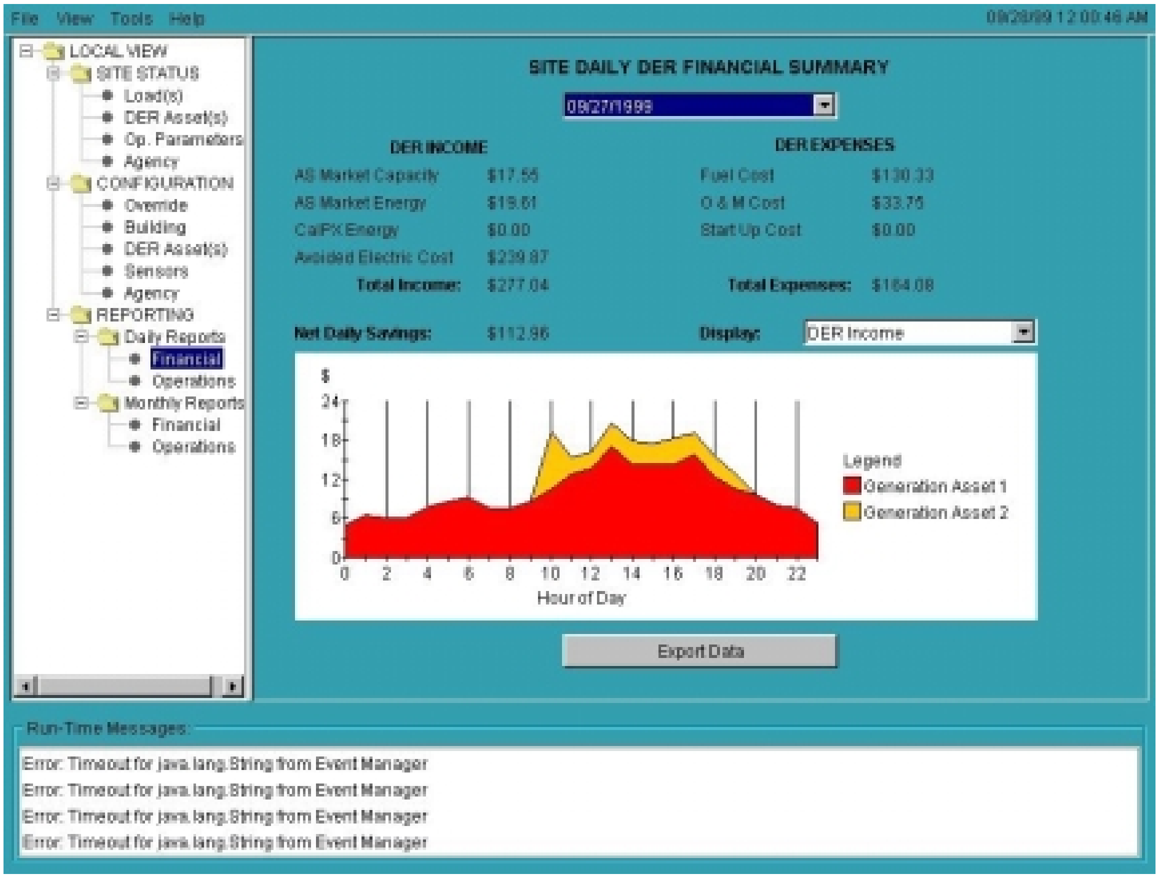

Figure 14. Single Site Financial Results for 9/27/99

While the financial benefits to the site were minimal for this particular day, it is important to note that *Smart**DER operation in this case resulted in additional capacity being made available to the California marketplace. In the absence of *Smart**DER it is likely that this capacity would have either operated at low loads to offset site load or not operated at all.

2.4.1.8 Test Results - Dual Site, Multiple DER Assets

For the dual site test example we retained the large commercial site with its two 200 kW generators and added a second site with a small commercial load profile and two smaller generators totaling 175 kW in capacity. Each site was represented by a *Smart**DER agency operating on separate personal computers. As noted previously, the example test day was September 28, 1999 with sites assumed to be located in San Diego.

Test results are presented for each individual site and then for the portfolio of assets that were offered for participation in the California market(s).

<u>Large Commercial Site Results – 9/28/99</u>

Results of *Smart**DER agency operation under operating conditions (weather, site load and pricing) that existed on September 28, 1999 are illustrated in the Site OIA screens show in Figures 15, 16 and 17. Figure 15 graphically depicts the DER operating schedule that was planned and subsequently implemented.

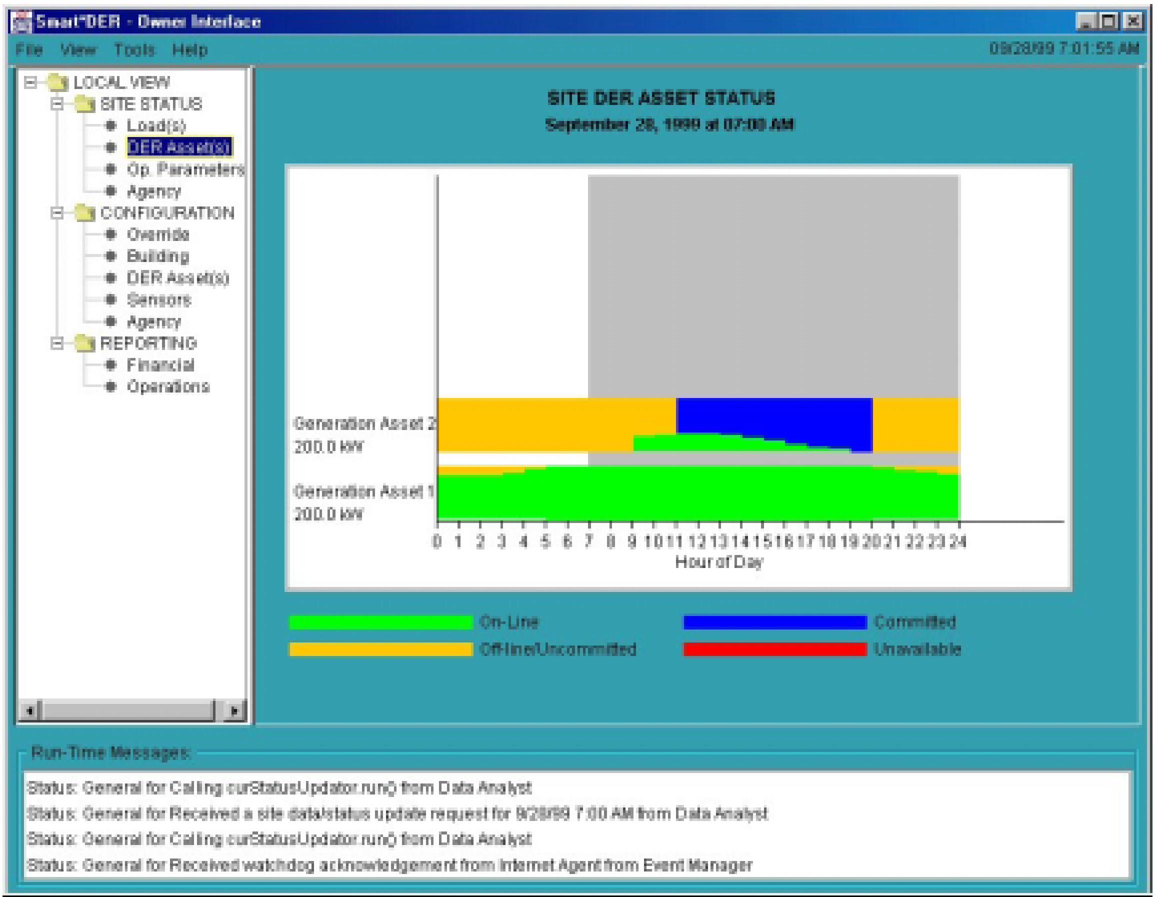

Figure 15. Large Commercial Site DER Operating Schedule for 9/28/99

The schedule is similar to the one developed for September 27th in that it shows continuous operation (shown as green) of the more efficient generator (Generation Asset 1) to satisfy site load. Operation of the second asset begins at 9 a.m. and continues until 7 p.m. In this case the second asset operates earlier and longer due to the higher energy costs (Figures 8-11) that existed on the 28th relative to the 27th. The resulting site load (net after generation) for the 28th is shown in Figure 16. Note the absence of any site load after 9 a.m. when the second generating asset was brought on-line.

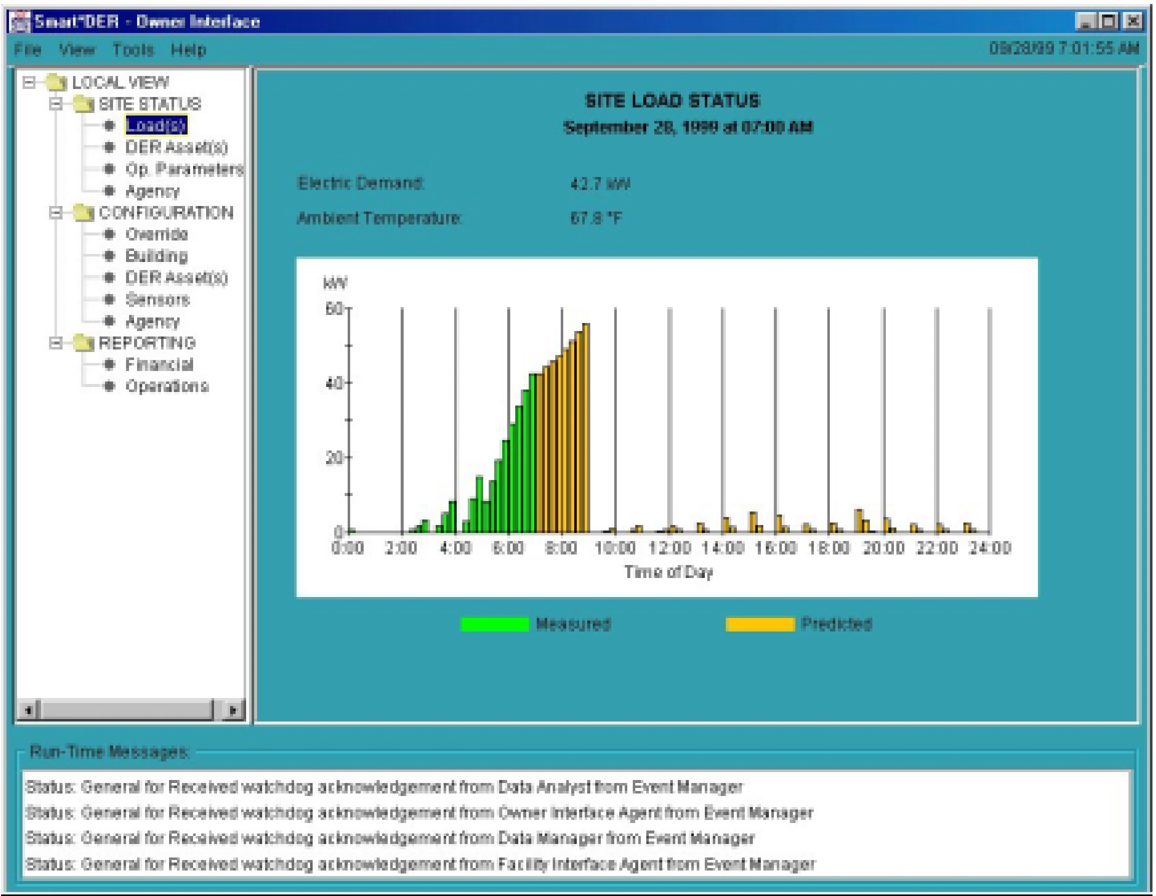

Figure 16. Large Commercial Site Load Status for 9/28/99

The financial results for operation of the large commercial site on September 28th are shown in the OIA GUI, Site Daily DER Financial Summary screen depicted in Figure 17. A net saving of $508 was achieved for the day, which is significantly higher than the $113 reported for the 27th (see previous Figure 14). The majority of the income is derived from avoided electric costs but income due to participation in the AS market increased to $212 from the $37 reported for the 27th.

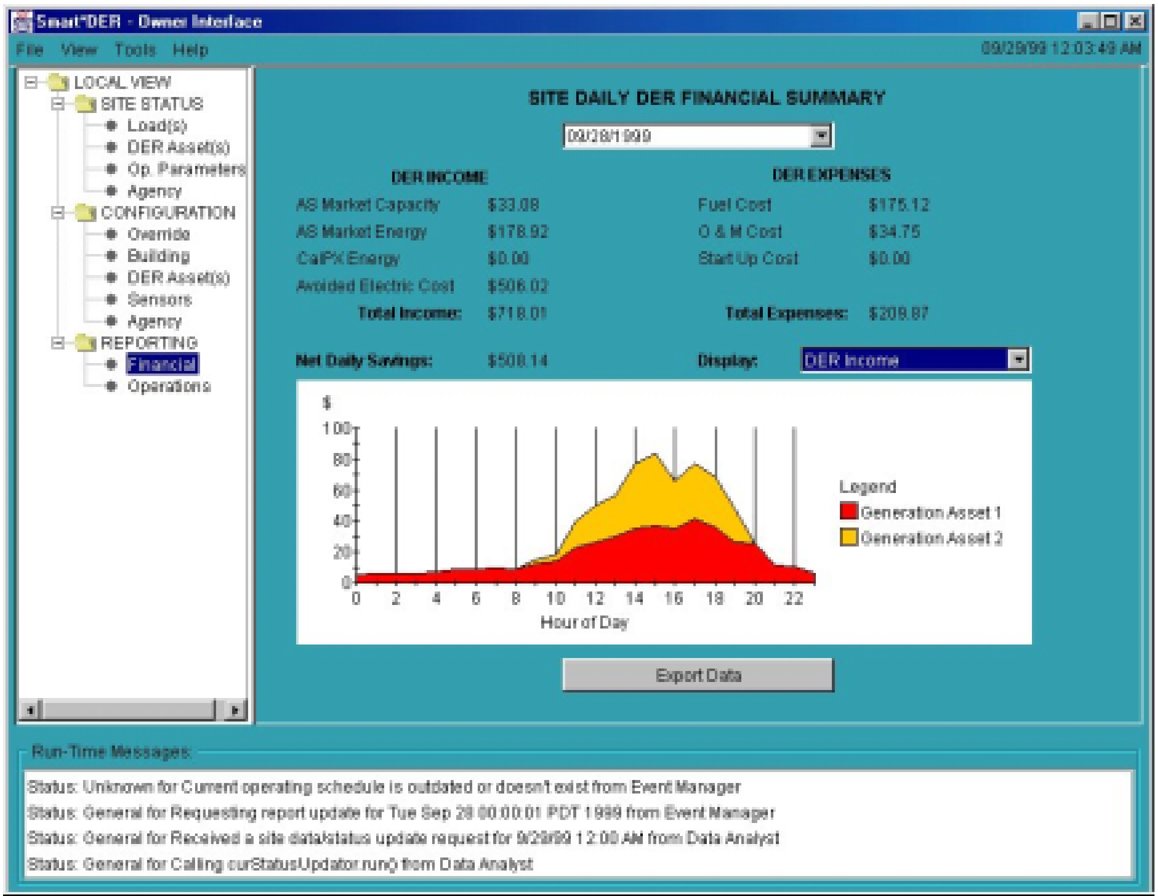

Figure 17. Large Commercial Site Financial Results for 9/28/99

Small Commercial Site Results – 9/28/99

Results of *Smart**DER agency operation for the small commercial site under operating conditions (weather, site load and pricing) that existed on September 28, 1999 are illustrated in the Site OIA screens show in Figures 18, 19 and 20. Figure 18 graphically depicts the DER operating schedule that was implemented and Figure 19 shows the resulting net site electric demand. The DER operating schedule shows that *Smart**DER did not schedule any unit operation prior to 7 a.m nor after 11 p.m. Operation of either unit during these periods would not have provided sufficient income to offset the operating costs. Operation (shown as green) of the first, more efficient, reciprocating type generator to offset site load began at 7 a.m. with operation of the less efficient generation asset beginning at 11 a.m. to offset the midday peak. *Smart**DER committed the remainder of the second asset's capacity to the AS market (shown as blue) beginning at 1 p.m. and continued to do so until 8 p.m. to take advantage of elevated AS prices occurring in the afternoon. (Figure 9). In addition, *Smart**DER committed excess capacity from Generation Asset 1 during the hours of 5 p.m. to 8 p.m., again to take advantage of high AS market prices.

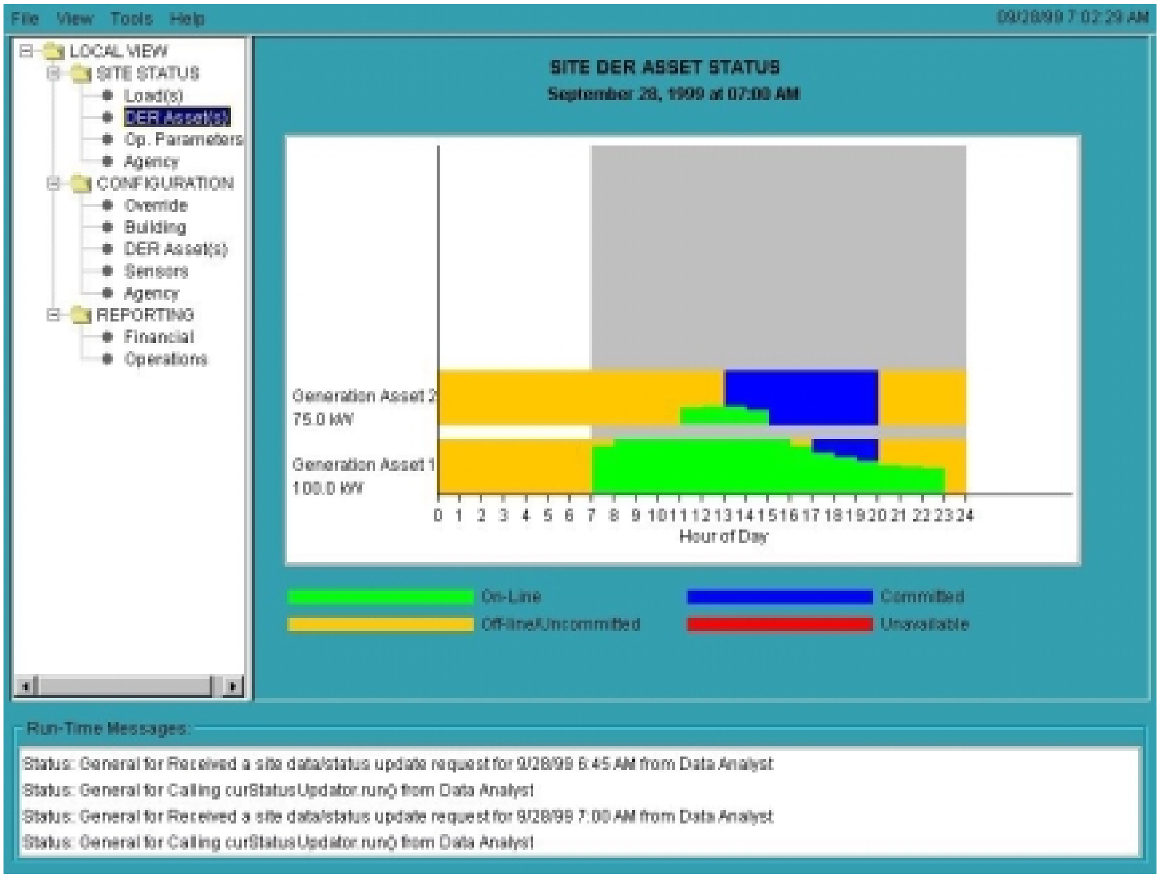

Figure 18. Small Commercial Site DER Operating Schedule for 9/28/99

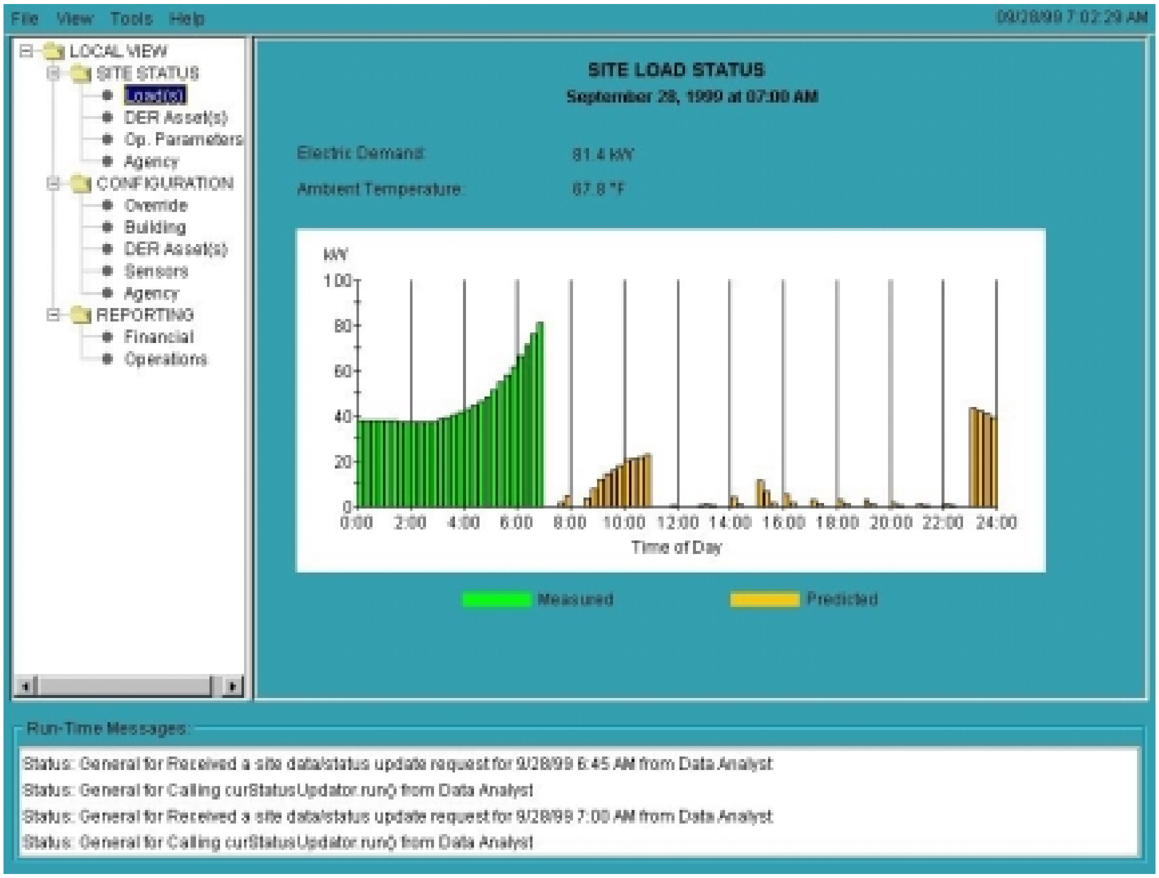

Figure 19. Small Commercial Site Load Status for 9/28/99

The financial results for operation of the small commercial site on September 28th are shown in the OIA GUI, Site Daily DER Financial Summary screen depicted in Figure 19. A net saving of $186 was achieved for the day with a significant portion of the $275 income for the day derived from participation in the AS market.

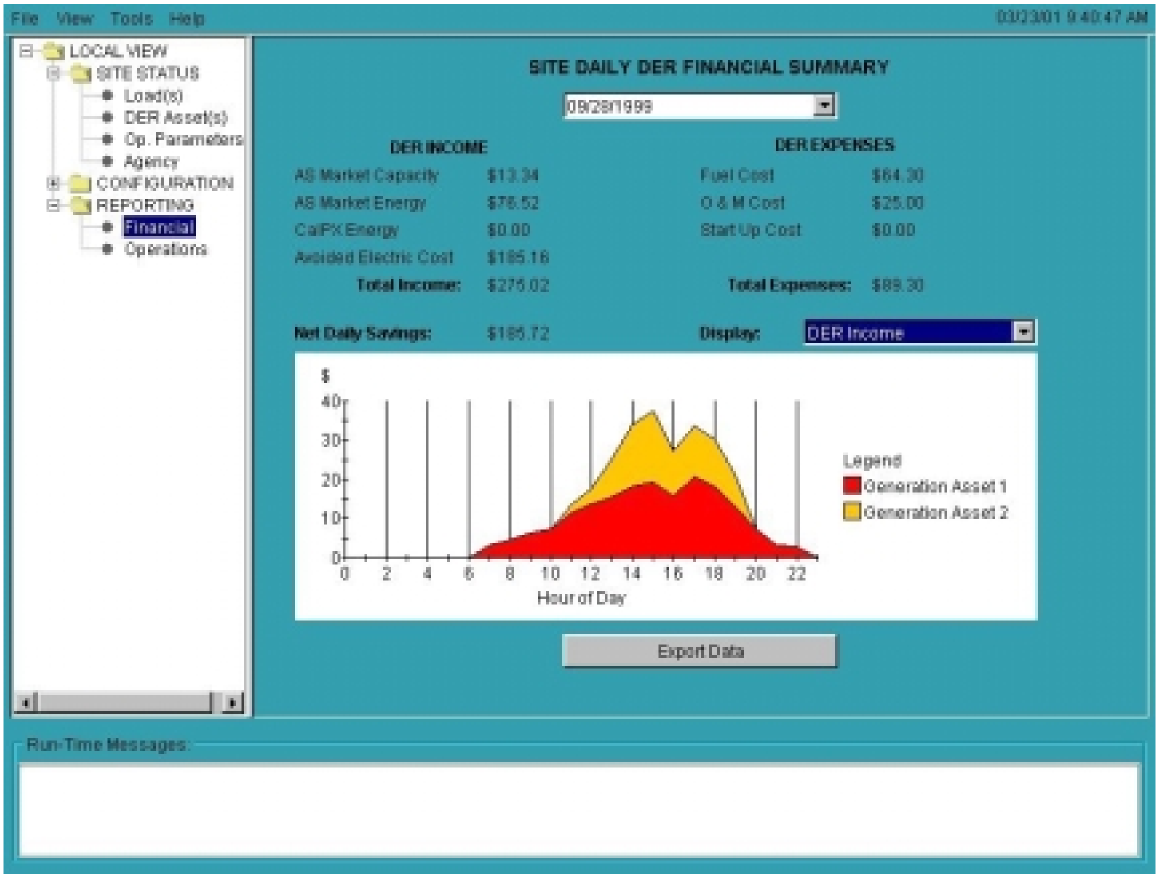

Figure 20. Small Commercial Site Financial Results for 9/28/99

It should be reiterated that operation of Generation Asset 2 would have been minimal in the absence of *Smart**DER. The capacity of this asset as well as a portion of the first generation asset's capacity became available to the California marketplace as a result of *Smart**DER operation.

<u>Portfolio Results – 9/28/99</u>

The Portfolio Manager OIA screens, shown in Figures 21, 22 and 23, illustrates portfolio results for operation on the September 28, 1999. The Generation Status Screen shown in Figure 21 graphically depicts the status of the generation asset contribution (both committed and generated) of each site to the portfolio. In this case, the graph shows that the large commercial site (designated as SDGE_Lead) has committed between 125 kW and 200 kW of capacity between the hours of 11 a.m. and 7 p.m. in support of portfolio commitments. The small commercial site (designated as Small_Commercial) is also shown to provide generation capacity in support of portfolio operations between 1 p.m. and 7 p.m. Note that this screen shot was taken at the beginning of the day immediately following the initial bidding cycle (see time stamp of "September 28, 1999 at 12:00 AM" located below the screen title). As such this screen would only show commitment of capacity since at that point in time no unit operation would have occurred. Actual operations that occurred during the day are summarized in the Portfolio Daily

Operations Summary screen shown in Figure 22. This figure shows that both sites generated power in support of the AS market between the hours of 1 p.m. and 7 p.m. with a peak contribution of 316 kW of generation (200 kW for SDGE_Lead and 116 kW for Small_Commercial) at 7 p.m.

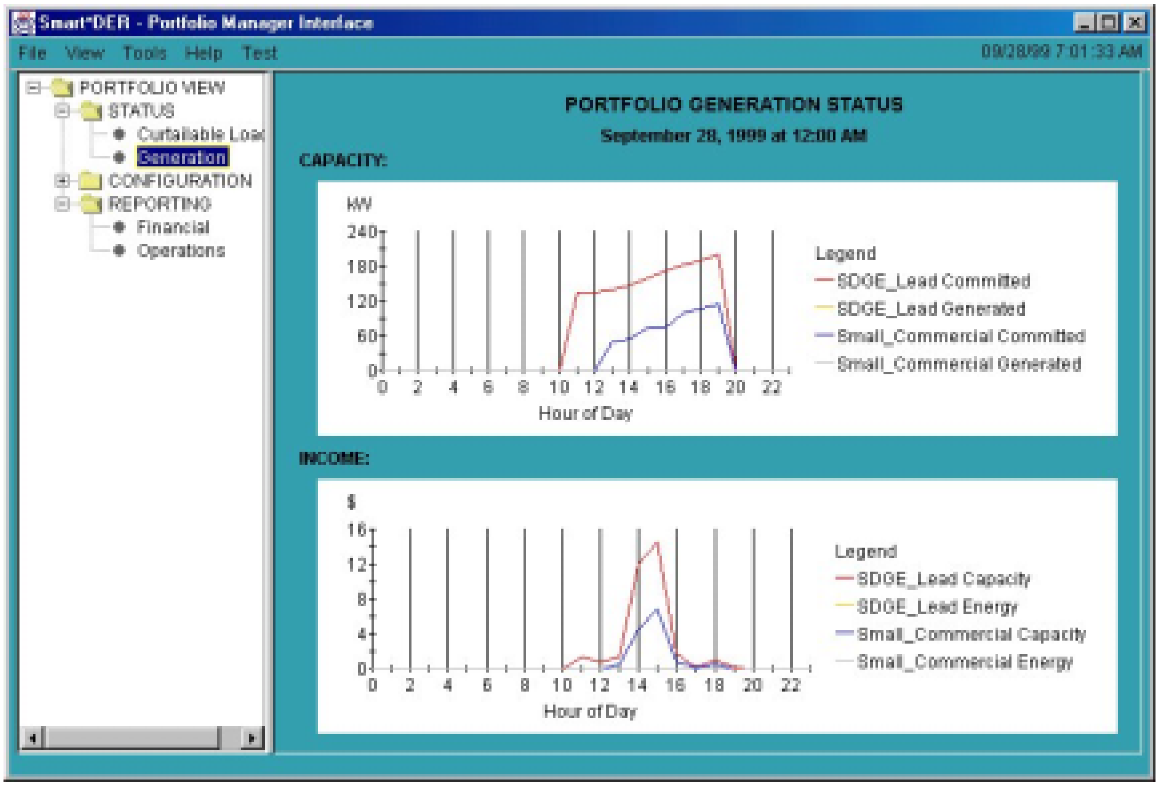

Figure 21. Portfolio Generation Status for 9/28/99

The Portfolio Daily Financial Summary screen (Figure 23) summarizes the income associated with portfolio operations and graphically shows the income attributable to each site. Additional detail (not shown) in the form of a tabulated site breakdown for a given hour is provided by clicking on an individual hour in the graph. For this date, the portfolio earned income associated with both the sale of generating capacity and energy (after the call for capacity was received) into the AS Replacement Reserve market.

The financial results of this particular day and for these individual sites were modest. However, it is clear that the magnitude of the financial results is simply a function of the size and number of the assets involved. The truly important result is that *Smart**DER agencies successfully collaborated to schedule and aggregate the assets at multiple sites, which allowed assets to participate in the marketplace that would otherwise have been excluded.

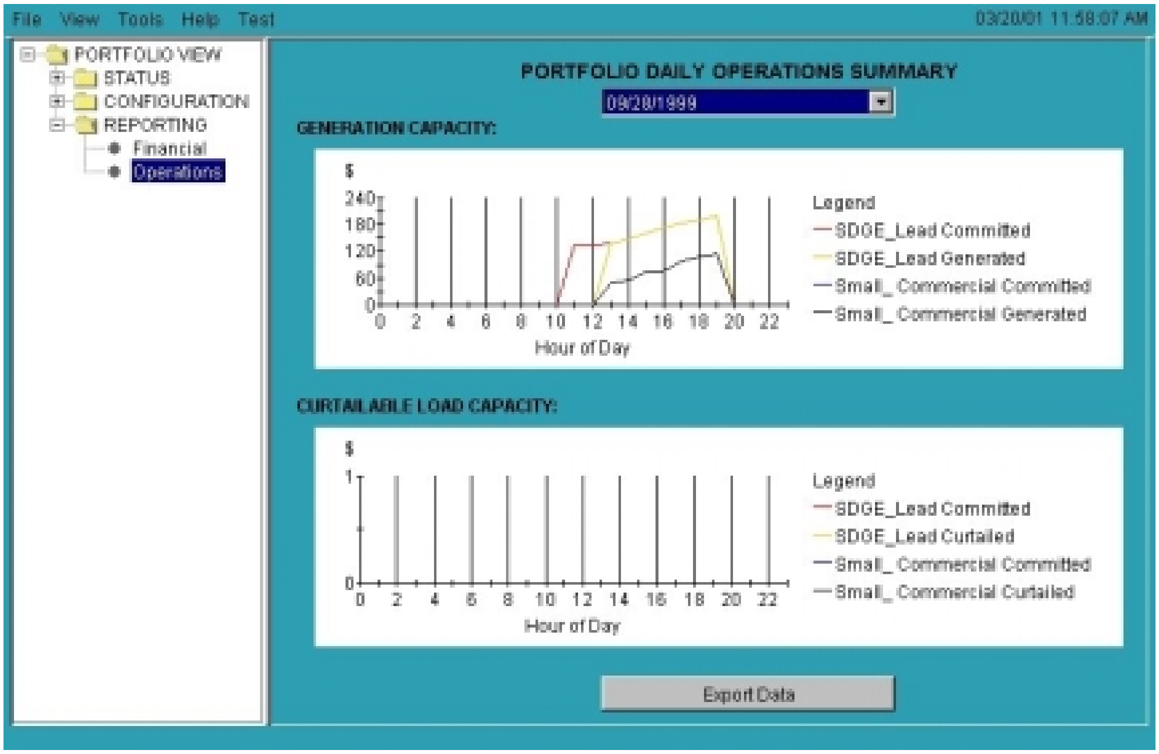

Figure 22. Portfolio Daily Operations Summary for 9/28/99

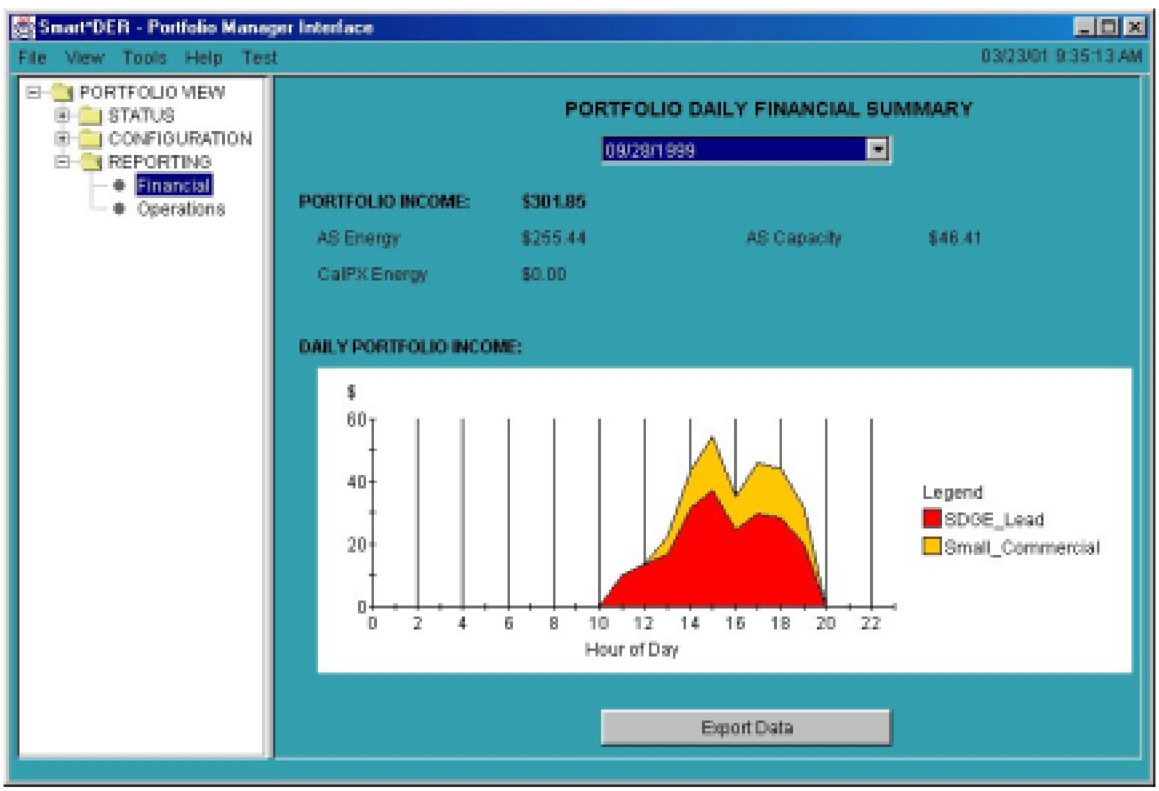

Figure 23. Portfolio Daily Financial Summary for 9/28/99

2.4.1.9 Integration Testing Summary

*Smart**DER agency operation is both simple and complex. It is simple in that each individual agent is designed to have a relatively small number of functions and tasks. It is complex in that each agent communicates with one or more other agents in order to carry out its tasks. In turn, an agency of agents must communicate with other agencies to represent the interests of an individual site. Testing was therefore carried out as a three part process where:

- Basic functionality of each agent was checked and confirmed,
- Inter-Agent communications were checked and confirmed, and
- Agents were combined into agencies and operated in a simulated environment (EASE) to verify that agencies could function independently yet collaborate to schedule DER asset operation in response to dynamic price and weather conditions.

At each of these steps AESC and its principal subcontractor, Reticular Systems were able to confirm that agents and agencies were operating correctly.

Ultimately, testing confirmed that *Smart**DER agents, operating in response to 1999 AS and energy market pricing, were able to collaborate and therefore aggregate the capacity of DER assets into a portfolio of assets that could in turn participate in the marketplace.

2.5 Task 5 DER*S Documentation and Demonstration Development

The purpose of this task was develop a technology transfer tool that would assist us in moving *Smart**DER agent technology beyond the proof of concept stage. To accomplish this we needed to develop demonstration software suitable for approaching and informing end-users and equipment manufacturers about *Smart**DER agent technology. This task also provided for development of a demonstration software user's manual suitable for use by industry personnel. This demonstration software and manual would be provided to the both the Commission Contract Manager and virtual evaluation group for their review and comment.

AESC and its principal subcontractor, Reticular Systems, Inc. provided the following deliverables prior to completion of the Task 5 effort:

- Copy of the demonstration software
- User’s manual for the demonstration software

2.5.1 Task 5 Results

Under this task AESC was to develop demonstration software and associated documentation that would facilitate transfer of intelligent agent technology into the private sector. This software would then be demonstrated and subsequently provided to the market participants for their review and feedback.

2.5.1.1 *Smart**DER Software Demonstration

AESC developed a PowerPoint presentation (Appendix IV) and associated *Smart**DER software demonstration, which were presented to the Commission at a March 13, 1999 meeting held at the Commission's offices in Sacramento, California. Commission staff members as well as a number of the market participants were in attendance.

Market Participant Feedback

Valuable feedback on the *Smart**DER interface screens as well as feedback on the major issues facing *Smart**DER implementation was obtained during the meeting. Participant feedback is briefly summarized below.

1. OIA GUI screens that display DER asset status didn't provide sufficient information. This screen displayed either commitment of capacity or operation but could not provide an indication when both conditions applied during the same hour of operation. DER asset status would appear as green (on-line) if any portion of the generator's capacity was on-line. Therefore, information on partial commitment of capacity to the AS market was not displayed if the unit was also on-line to offset site load during a given hour. This screen (see previous figures 12,15,18) was subsequently modified to show both on-line and AS market commitments during any hour.

2. OIA GUI screens that display load status didn't provide sufficient information on the contribution of the various generating assets. This screen (see previous figures 13, 16, 19) displayed the net site load after generation was subtracted and as such did not display any information on the output of individual generating units. Conversion of this screen to a stacked bar graph showing the contribution of the various assets is planned.

3. The benefit of *Smart**DER use of JAVA code and the platform independence that this provides was questioned. The response was that one of the primary strengths of the agent-based approach is the ability to locate agents on separate platforms. For instance, it is conceivable that the OIA would be located on a personal computer located in the Facilities Department of a large complex while the Data Manager (DM) could be located on a Unix server located in the Information Systems department. This multi-platform capability was fact confirmed by AESC and Reticular Systems during testing.

4. It was observed that reliance on a single Portfolio Manager (PM) agent to represent the interests of multiple sites makes the system vulnerable in the event that this agent were to go off-line. The question was raised if it was possible to have more than one PM agent so that an alternative would be available in the event that the primary PM crashed. The response was that this is entirely possible. Communications between agents could easily accommodate multiple PM agents and if fact AESC had proposed a similar system as part of a 1997 Army Small Business Innovative Research (SBIR) grant proposal.

5. The question was raised as to the maximum number of sites that an individual PM agent could handle. The response was that the data analysis performed by the PM was relatively simple and would not be limited to any particular number of sites. The computational burden is handled at each site with the PM simply processing the intrasite bid information. In addition, it was explained that the system was envisioned as having a separate PM agent for each CAISO zone since the CAISO had indicated that portfolio bids involving multiple zones would not be permitted. This restriction would help to limit the number of sites handled by a single PM.

   The question was clarified to state that the number of transactions and data storage needed for billing true up and settlement could prove burdensome for the PM as additional sites were added (especially in light of CAISO data requirements). One of the market participants observed that settlement and true-up are not done in real-time and could therefore be handled as separate data processing streams. An agent-based technology easily accommodates this approach since the DM agent could readily be attached to an existing legacy system that would perform the needed data storage and processing.

6. The issue of network security was raised. An observation was made that it was not clear how an intelligent agent based system would prevent intrusion by unauthorized personnel. The response was that security is handled at two levels. The AgentBuilder® software that serves as the basis for the agents themselves handles security at the agent communication level while higher level security is handled by the network infrastructure software such as that offered by Enflex, Encorp or Sixth Dimension. It was reiterated that *Smart**DER technology is envisioned as a supervisory software layer that would ultimately reside with the infrastructure networking software produced by others. One of the market participants offered that networking software routinely handles higher level security.

2.5.1.2 *Smart**DER Demonstration Software Distribution

Based on discussions with the Commission Program Manager a decision was made to temporarily withhold distribution of the demonstration software. While the demonstration software could have been made available for participant use it was decided that distribution of the software would risk the loss of valuable intellectual property. The JAVA based demonstration software could too easily be disassembled and the risk of loss was too great. Therefore a decision was made to provide demonstrations of the software on a company by company basis with AESC providing software for use at a later date once steps could be taken to protect both AESC's and the Commission's investments.

2.6 Reporting Tasks

The following reporting tasks were undertaken by AESC in accordance with PIER project requirements.

2.6.1 Task 3.1 Monthly Progress Reports

AESC prepared and submitted written Monthly Progress Reports to the Commission Contract Manager by the 30th of each month during the course of the project.

2.6.2 Task 3.2 Final Report

AESC prepared and submitted to the Commission Contract Manager for review an outline of the Final Report describing the original purpose, approach and results of the project. Upon receipt of outline approval AESC prepared and submitted to the Commission Contract Manager a draft Final Report on the project. Upon finding the revised draft to be satisfactory, the Commission Contract Manager provided a written notice of draft approval. AESC then prepared and submitted the Project Final Report.

2.6.3 Task 3.3 Final Meeting

At the conclusion of the project AESC met with the Commission Contract Manager to present findings, conclusions, and make recommendations for next steps.

3.0 Project Outcomes

The discussion of project outcomes is divided into two areas. First, project outcomes will be summarized relative to the various project tasks described previously in the Project Approach section. Second, a discussion of project outcomes as they relate to the project's technical and economic objectives is provided.

3.1 Project Outcome by Technical Objective(s)

The project technical objectives were achieved during the course of the project. The two technical objectives for this PIER project were to:

- Demonstrate how a prototype network of intelligent software agents can coordinate and schedule one or more distributed energy resources.
- Develop a demonstration package that will facilitate transfer of the project results into the private sector.

The first project technical objective was achieved during the testing and integration tasks when AESC and Reticular Systems confirmed:

- operation of individual *Smart**DER agents,
- agent-agent communications,
- agency communications with external, web-based entities in order to retrieve pricing and weather data needed for routine *Smart**DER operation, and
- *Smart**DER agency operation to schedule DER assets in response to market and weather conditions for dates in 1999 (see Section 3.1.4).

The second technical objective called for development of a demonstration package that would facilitate transfer of the project results into the private sector. AESC developed a PowerPoint presentation (Appendix IV) and associated *Smart**DER software demonstration, which were presented to the Commission at a March 13, 1999 meeting held at the Commission's offices in Sacramento, California. Commission staff members as well as a number of the market participants were in attendance. During this meeting both single and multiple agency operation were successfully demonstrated. Distribution of demonstration software was deferred until a later date based on discussions with the Commission Program Manager. It was decided that distribution of the software would risk the loss of valuable intellectual property since JAVA based demonstration software could too easily be disassembled and examined. In lieu of providing the software, AESC will demonstrate the software on a company-by-company basis. AESC will provide the demonstration software for use at a later date once steps have been taken to protect both AESC's and the Commission's development investments.

3.2 Project Outcome by Economic Objective(s)

AESC achieved the project's single economic objective, which was to:

- Identify and initiate discussions with one or more potential partners who are willing and able to participate with commercialization of the DER*S agency.

During the course of the project AESC engaged a variety of market participants with the potential to assist in further commercialization of *Smart**DER technology. AESC contacted many of these individuals as part of the Market Research and Domain Analysis efforts (see Section 3.1.1). Many of the participants contacted chose to participate in the Virtual Evaluation Group that subsequently provided valuable feedback during the project.

In addition to the market research and domain analysis tasks, AESC attended CAISO meeting(s) as well as three distributed generation conferences. AESC presented the project at the 1999 CADER (California Alliance for Distributed Energy Resources) conference in November 1999 and also attended the 2000 CADER conference. AESC also visited the Distributech conference in February 2001. As a result of these activities AESC established dialogues regarding *Smart**DER development with:

- Distribution generation equipment manufacturers (e.g., Caterpillar, Honeywell), and
- Network infrastructure software/hardware developers (e.g., ASCO, Encorp, Enflex, Engage Networks, Silicon Energy, Sixth Dimension, C3 Communications).

Of those contacted, companies that provide network infrastructure products have expressed the most interest in *Smart**DER technology. These companies represent the best near-term commercialization partners since *Smart**DER technology could be readily integrated with the software/hardware products that they already offer. The current status of discussions with these companies is focused on potential demonstrations that would provide for integration/interface of *Smart**DER technology with their product/technology for installation and testing at one or more sites in California.

4.0 Conclusions and Recommendations

4.1 Conclusions

Overall, this PIER project has been highly successful since all of the technical and economic objectives were achieved. AESC and its principal subcontractor, Reticular Systems successfully developed the Internet-based *Smart**DER intelligent agent software and subsequently confirmed the functionality of the various agents while operating in response to market conditions for dates in 1999. Single and multiple agency testing confirmed that *Smart**DER agents, acting on behalf of individual sites could collaborate to schedule DER asset operation. Testing indicated that *Smart**DER operation enabled sites with excess generating capacity to collaborate for purposes of aggregating this capacity and subsequently participating in the CAISO AS markets. In other words, testing showed that *Smart**DER technology brought generating capacity to the California marketplace that would not otherwise have been able to participate. AESC successfully demonstrated the *Smart**DER intelligent agent software at the Commission's Sacramento offices on March 13, 2001.

As part of the Market Research and Domain Analysis efforts AESC engaged a variety of market participants in a Virtual Evaluation Group that provided valuable feedback on *Smart**DER product requirements and operating scenarios. This information was used to develop a product specification that further guided the product design and development process. In addition to its involvement with the Virtual Evaluation Group AESC also participated in three industry conferences and CAISO meetings related to distributed generation. As a result of these efforts AESC was able to establish dialogues with a variety of companies interested in continued development of *Smart**DER technology. Companies that currently market network infrastructure software such as Encorp, Enflex and Sixth Dimension have expressed an interest in exploring additional efforts where *Smart**DER technology can be used in conjunction with their products.

Intelligent agent technology represents a fundamentally different way of addressing the DER asset-scheduling problem. Use of intelligent agent technology provides for a distributed decision-making solution where centralized decision making processes are currently being applied. This fundamental shift in thinking makes the job of transferring this technology into the private sector more difficult since it requires that potential users change the way that they view the problem (and solution). During the project AESC succeeded in bringing this intelligent-agent technology to a Stage 3 (Bench testing / proof of concept) level of development. In addition, AESC laid the groundwork for further development beyond Stage 3 by developing and demonstrating software that can be used to facilitate the Stage 4, Product Development and Field Experiments as well as establishing dialogues with potential commercialization partners.

4.2 Benefits to California

There is little question that integration of DER assets into the marketplace, the overriding premise behind this PIER project, continues to be of paramount importance. Intelligent software agents with their ability to communicate and collaborate are well suited to the task of scheduling and coordinating the activities of large numbers of DER assets. Use of intelligent software agents in this fashion reduces the level of expertise needed to own and operate distributed energy resources, which in turn, allows greater participation by owners of distributed energy resources in California's competitive energy industry. The benefits of this project are therefore tied to the benefits of increased DER participation in California’s deregulated marketplace:

- Improved system reliability, power quality, VAR control, and reduced reliance on must-run generation
- Reduced distribution system congestion, avoidance of distribution line losses and deferral of system upgrade / construction
- Customer cost reduction by direct displacement of load
- Energy price reduction (as new DER assets displace existing load and / or centralized generation)

4.3 Recommendations

One need only look at the daily newspaper to appreciate the dynamic nature of the California marketplace. There is little question that integration of DER assets into the marketplace, the overriding premise behind this PIER project, continues to be of paramount importance. In 1998, when this project was first proposed there were four basic avenues for DER interaction in the deregulated marketplace. First, DER assets could be used to offset site loads to provide cost savings associated with utility bill reduction. Secondly DER assets could be used in conjunction with UDC sponsored interruptible rates. Third, DER assets, if aggregated in sufficient numbers, could bid into the energy spot market run by the CalPX. And fourth, aggregated DER assets could participate in the ancillary services auction run by the CAISO. Specific procedures and protocols for DER participation in the marketplace did not exist at the time this project was initiated. A great deal of progress has been made in the development of these procedures and protocols since this project officially began in May 1999. The energy spot market and the CalPX itself no longer exists but there are now five separate programs, either in place or pending that will provide for participation by DER assets. These programs now include:

- CAISO ancillary services (AS) auction (Supplemental energy, ancillary services),
- UDC sponsored interruptible rate tariff participation,
- CAISO DRP (demand relief program) (new program for 2001),
- CAISO DLCP (discretionary load curtailment program) (new program for 2001), and
- Energy Commission Electricity Peak Load Efficiency Grant Program (AB970) (new program for 2001).

Each of these programs has different requirements for participation, varying communication procedures and different verification / reporting requirements. Coordination of DER assets, especially in cases where aggregation of large numbers of assets is necessary has increased in importance. Clearly our efforts to facilitate integration of DER assets into the California marketplace are now more important than ever.

The existing project has brought this innovative agent technology to a Stage 3 (Bench testing / proof of concept) level of development and has also laid the groundwork for a successful Stage 4 development and testing effort. Potential commercialization partners have already expressed an interest in such an effort and AESC has developed the software to a level sufficient to move forward with the Stage 4 development effort.

It is for these reasons that AESC recommends that the Commission fund a follow-on PIER effort that would move this technology forward to completion of Stage 4. This effort would involve the following:

- Review and Evaluate the Feedback from the existing project,
- Identify Feasibility Field Test Participants,
- Refine the Smart*DER Technology and Integrate / Interface it with existing network infrastructure software products,
- Conduct a Feasibility Field Test For Control of Actual Loads

For Additional Information

For additional information on application of *Smart**DER technology or the potential benefits of applying intelligent software agents in general contact:

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Vice President
Alternative Energy Systems Consulting, Incorporated
858-560-7182
gibsonj@aesc-inc.com

5.0 Glossary

AESC	Alternative Energy Systems Consulting, Incorporated
AS	Ancillary services markets
CADER	California Alliance for Distributed Energy Resources
CAISO	California Independent System Operator
CalPX	California Power Exchange
Commission	California Energy Commission
DA	Data Analyst
DER	Distributed Energy Resources
DLCP	Discretionary load curtailment program
DM	Data Manager
DRP	Demand relief program
EASE	EnerAgent Simulation Environment
EM	Event Manager
EPRI	Electric Power Research Institute
ESCO	Energy Service Company
FIA	Facility Interface Agent
GUI	Graphical User Interface
I/O	Input/Output
IA	Internet Agent
ISO	Independent System Operator
kW	kilowatt
kWh	Kilowatt-hour

MCP	Market clearing price
NSPIN	Non-spinning reserve capacity
OIA	Owner Interface Agent
PAC	Personal action classes
PBR	Performance based ratemaking
PC	Personal computer
PG&E	Pacific Gas and Electric Company
PIER	Public Interest Energy Research
PM	Portfolio Manager Agent
PX	Power Exchange
Reticular	Reticular Systems Inc.
REPL	Replacement reserve capacity
SBIR	Small Business Innovative Research
SC	Scheduling Coordinator
SDG&E	San Diego Gas and Electric Company
TCP/IP	Transmission Control Protocol / Internet Protocol
UMCP	Unconstrained Market Clearing Price
UDC	Utility Distribution Company

Appendix I
Market Research Report

Appendix II
Final Domain Analysis Report

Appendix III
Virtual Evaluation Group Participants

Type	Name	Association	Position
DG & Control Mfg	Mark Skowronski	Honeywell (formerly Allied Signal Power Systems, Inc.)	
ISO	Dave Hawkins	CAISO	Principal Engineer
DG Mfg	Eric Wong	Caterpillar	Product Consultant
UDC	Carlos Martinez	Southern California Edison	Manager
Ctrl Supplier	Scott Castalaz	Encorp	VP Marketing
Ctrl Supplier	David Wolins	EnFlex	VP Marketing
Researcher	Chris Marnay	Lawrence Berkeley National Laboratory	Staff Scientist
Loc Gov	Kurt Kammerer	San Diego Regional Energy Office	Director
UDC	Vic Romero	SDG&E	
Individuals listed below were approached after formation of the initial evaluation group & expressed an interest			
Ctrl Supplier	Rich Weiss & Ken Brickner	Engage Networks	National Sales Manager
Ctrl Supplier	Charles DeWitt	C3 Communications, Inc.	Manager, New Service Offerings
Ctrl Supplier	Pat McMillan	Sixth Dimension	Director -- Product Marketing
Ctrl Supplier	Mark Czopek	HESI	Sr Consultant - Business Development
Ctrl Supplier	Jim Moeller	Stonewater Software Inc.	Acct Manager
Hardware Supplier	Jay Tucker	ASCO	Sr Field Sales Engr
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Appendix IV
Demonstration Meeting Presentation

Appendix V
Follow-on Effort Summary

Appendix I
Market Research Report

Appendix I
Market Research Report

CEC-PIER Project 500-98-040
Intelligent Software Agents for Control and Scheduling of Distributed Generation

Market Research
Final Report

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LEGAL NOTICE

Executive Summary

Alternative Energy Systems Consulting, Inc. (AESC) is currently under contract to the California Energy Commission (CEC) for development and demonstration of a Distributed Energy Resources (DER) scheduler that will operate in the California competitive energy marketplace. Specifically, the CEC-PIER project titled, “Intelligent Software Agents for Control & Scheduling of Distributed Generation”, provides funding to demonstrate the viability of controlling and scheduling one or more distributed energy resources using intelligent software agents; where an intelligent agent is a software program that acts on behalf of the user and has the ability to exploit knowledge, tolerate errors, reason with symbols, learn and reason in real time, and communicate with other agents or entities. Multiple agents acting independently, in a cooperative fashion, are called an agency. For this project we will develop and test a prototype agency called the Distributed Energy Resource Scheduler (DER*S).

This report summarizes the market research effort associated with the subject project. The market research effort had four basic objectives, which were to:

- Establish a market participant evaluation group comprised of knowledgeable key individuals and companies.

- Solicit comments from the market participant group on key issues and questions that affect DER*S.

- Form a Virtual Evaluation Group of engaged market participants that will provide valuable feedback on project activities for the duration of the project.

- Identify potential DER*S commercialization partners.

Relative to these objectives our market research efforts were very successful in that we were able to achieve all of the stated objectives. During the market research effort, we assembled a diverse market participant group consisting of knowledgeable individuals that were well suited to providing the desired feedback. Ultimately, the group provided valuable comments that are reflected in changes that were made to the project’s Preliminary Domain Analysis Report.

Overall, the market participant group found our description of the California electric market(s) to be both accurate and well written. Panel members understood the DER*S concept and confirmed the need for new scheduling and dispatch technologies. These technologies are necessary to facilitate widespread DER operation and grid integration. Panel comments will enable us to refine the DER*S and demonstration software designs to better accommodate the needs of the market.

The market participants agreed with our initial assessment of how DER*S could be integrated into the California marketplace but indicated that we were overly focused on the bulk power and ancillary services markets. We subsequently made changes that will provide for DER*S management of curtailable loads in response to either interruptible electric rates and/or the ancillary services markets. In addition, we now recognize the importance of DER*S operation at an individual site to directly offset facility utility costs without any need for involvement in either the bulk power or ancillary services markets.

Market participant comments compelled us to refine the DER*S market/operating scenarios that we identified in our Preliminary Domain Analysis Report. We were further able to identify DER*S near- and long-term operating scenarios, which will in turn allow us to focus the DER*S and demonstration software designs.

A Virtual Evaluation Group (VIREG) consisting of individuals that participated in our market participant group was formed. We had initially envisioned a relatively large base of market participants from which to choose VIREG participants. What we found was that market participants that had provided comments did so because they had both an interest and desire to participate throughout the project. For this reason, the VIREG is comprised of all ten (10) of the market participants that provided comments/feedback.

It would have been premature to negotiate with, or otherwise engage, a commercial partner given the early stage of our project. However, we were able to identify the commercial partner traits that will maximize the benefit to the DER*S development and commercialization efforts. These traits call for a commercial partner that has:

- ✓ An existing product or technology that enhances potential DER*S market penetration,
- ✓ An existing product distribution / support infrastructure, and
- ✓ Industry Name / Trademark Recognition

In addition, we were able to identify potential commercialization partners having some or all of these traits. Some of these potential partners have agreed to participate in the VIREG. Other partners will be more approachable as the DER*S product design solidifies. We will therefore continue our efforts to identify additional potential partners as the project progresses.

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1.0 Introduction

This market research effort is part of the first task in a California Energy Commission PIER research and development project titled, "Intelligent Software Agents for Control & Scheduling of Distributed Generation". The overall project objective is to demonstrate the viability of using intelligent software agents for scheduling/dispatch of one or more distributed energy resources (e.g., distributed generation, energy storage, cogeneration, etc.) in a competitive market. An intelligent agent is a software program that acts on behalf of the user and has the ability to exploit knowledge, tolerate errors, reason with symbols, learn and reason in real time, and communicate in an appropriate language. Multiple agents operating in conjunction, as an agency, can achieve goals/objectives that would not be otherwise achievable by a single agent. For this project we will develop and test a prototype agency called the Distributed Energy Resource Scheduler (DER*S) that will schedule operation of distributed energy resource (DER) equipment in a simulated competitive energy market.

There were four basic objectives of this market research effort:

- Establish a market participant evaluation group comprised of key individuals and companies that operate in, or have knowledge of, the competitive energy industry and/or distributed energy resources.

- Solicit feedback from the market participant group on key issues and questions that affect DER*S. This information would support our domain analysis efforts and ultimately help characterize the DER*S operating environment, or domain, for the most likely DER*S markets.

- Identify a smaller group of engaged market participants that will comprise a Virtual Evaluation Group (VIREG), which will continue to provide feedback on project activities during the course of the CEC PIER project.

- Identify potential DER*S commercialization partners

The remainder of this report is divided into five sections. Section 2, Market Participant Group describes the activities involved in identifying and forming the market participant group. Section 3, Market Participant Group Feedback, summarizes the feedback that was received and the its impact on DER*S. Section 4, Virtual Evaluation Group, discusses the purpose and formation of the Virtual Evaluation Group while Section 5, Potential Commercialization Partners provides an update on our activities to identify a commercialization partner for the DER*S technology. Section 6, Conclusions and Recommendations is self-explanatory.

2.0 Market Participant Group

A variety of sources were used to identify key market participants that operate in, or have knowledge of, the competitive energy industry and/or distributed energy resources. A number of individuals approached AESC directly after seeing the CEC PIER project description posted on the CEC website. In addition, AESC reviewed the following sources to establish the initial market participant group.

- ✓ California Public Utility Commission - Registered Energy Service Provider
- ✓ California Independent System Operator - Certified Scheduling Coordinators
- ✓ California Power Exchange - Participant Database
- ✓ NERC Western System Coordinating Council - Member Electric Utility Systems
- ✓ California Alliance for Distributed Energy Resources (CADER)
- ✓ California Large Energy Consumers Association
- ✓ California Retailers Association
- ✓ California Manufacturers Association
- ✓ Gas Research Institute
- ✓ Electric Power Research Institute

Using these data sources AESC developed an initial list of potential market participants containing information on 360 individuals and/or companies likely to manufacture, install, operate or otherwise interface with distributed energy resources. This list was further condensed to 111 individuals (see Appendix A) by removing multiple individuals from the same company and by removing companies that were not directly involved in the California marketplace. Because of the large size of the list we decided to target some participants for direct telephone contact and others for contact via a mailer. Of the 111 potential participants on the list, 70 received a mailer containing information on the project along with general information on AESC. A market participant group consisting of 10 individuals was ultimately identified in this manner.

Table 1 shows the breakdown of the market participant group members that have provided comments thus far. As the table shows, the market participant group contained a diversity of both academic and industry concerns as well as relevant regulatory agencies.

Table 1 – Market Participant Group Breakdown

Description	Company/ Agency
Utility Distribution Company (UDC)	2
UDC Affiliate (Non-regulated)	1
DER Manufacturer	3
DER Control Manufacturer	2
Regulatory Agency	1
National Lab	1
Total:	**10**

2.1 *Soliciting Market Participant Feedback*

AESC used three documents to first solicit participation and then subsequently obtain feedback from the market participant group. These documents and their use in obtaining market participant feedback are discussed in the following paragraphs.

Participant Briefing Paper – This was the first document (along with a cover letter requesting participation) sent to each potential participant (see Appendix B). This white paper, provided basic project information as well as information on intelligent software agent technology. This document was sent either as part of the mailer or as a follow-up to a telephone contact and was used to solicit project participation.

Preliminary Domain Analysis Report – This report contained a more in-depth discussion of the California energy industry and on the role of DER in this marketplace. Additional discussion on the DER*S concept and potential operating scenarios was also provided. This document was provided in hard-copy form to individuals that expressed an interest in participation and who had already received the project briefing paper.

Participant Survey – This survey (see Appendix D) consisted of eight basic questions that were developed to focus participant feedback in areas of greatest concern to the project. Each participant that received the Preliminary Domain Analysis also received the Participant Survey. To minimize the effort necessary to complete the form, each participant was provided an electronic version that could be modified and returned via e-mail.

3.0 Market Participant Group Feedback

Market participant group feedback was obtained in a variety of ways. Some participants provided written feedback on the documents that they received while others responded verbally via telephone conversations. Group comments are discussed below beginning with general comments on the Preliminary Domain Analysis Report followed by a summary of responses to the Participant Survey and then a discussion of how market participant feedback affected DER*S.

3.1 General Comments - Preliminary Domain Analysis Report

The overall response of the market participant group, after reviewing the Preliminary Domain Analysis Report, was positive. The panel provided comments regarding the high quality of the report with respect to its description of the California electric markets, the state of deregulation, and how DER fits into current and future market scenarios. The panel also identified and proposed changes in the description of DER controls and technology, which we incorporated into the Domain Analysis Final Report. We have summarized the panel responses for each section of the Preliminary Domain Analysis Report below.

DER*S Description

A comment that was repeated from several panelists was the suggestion that DER*S should also interact with load management controls to reduce grid demand in response to various price signals. Some suggested that our draft description of the markets focused too much on higher voltage and statewide connections (ISO & PX) and too little on local price and integrated supply/load control. One panelist directed us to a recently proposed change in the California ISO ancillary market protocols called the Participating Load Agreement, which would permit bidding of curtailable loads into the ancillary services markets as either non-spinning reserve or replacement reserve.

Another insight provided by the panel was the difference in price signal time cycles among each of the market entities. For some *price signals*[1], such as calls for ancillary services and transactions involving the ISO imbalance energy market may be close to real-time while other price signals such as PX bid and pricing data are daily cycles.

One panelist, who had been separately developing DER market scenarios under a DOE contract, had identified five basic market scenarios (see Appendix E for the white paper/report on this topic). These market scenarios included: 1) an expanded role for back-up generators, 2) operation of local micro-grids containing one or more DER and/or energy storage assets, 3) interconnected local micro-grids, 4) direct integration of DER in the utility distribution grid to meet T&D needs, and 5) integration of local micro-grids with utility T&D grids. After comparing these five market scenarios relative to our three

[1] Where the term "price signal" describes both dispatch and pricing signals.

market scenarios[2] we concluded that there was no conflict and we were able to confirm this during discussions with the panelist that had developed the scenarios. The differences between the market segmentation methods were actually just a difference in perspective. Our domain analysis had focused on market scenarios as defined by participant interaction while their market scenarios were segmented by the configuration of the DER. We believe both market segmentations are compatible since we can identify our three market interaction scenarios in each of their five market configurations.

There was some expression by the panel that more detail was needed on DER*S functionality. Since we are using the Domain Analysis Report as a foundation to define the DER*S features and functions, we felt that the panel was a little ahead of our project plan at this point.

California's Competitive Market

While the market participants agreed that our general description of the California market(s) was accurate there were few specific comments. The few remarks that were received indicated an interest in a more detailed description including examples. We felt that an exhaustive description of California's current electric market, while highly informative, would provide little additional value to the project. Such a detailed report would not provide sufficient new information and the expenditure of project funds could not be justified.

One panelist suggested that we add price values to Figure 6 (Electric Price / Cost Contributors). While we had considered supplying this information when developing the chart, we elected against it in order to illustrate the general concept of electric cost accumulation. Describing the electric value chain, in more detail by including exact price values would cause undue debate about their accuracy and detract from the intended purpose of the figure.

DER Technology Description

Panelists indicated that our DER technology descriptions had excluded any discussion of load management technologies (e.g., curtailable loads, HVAC set-point modification, etc.), which could play a significant role in the deregulated market. Based on these comments we added curtailable load to the DER technology list shown in Table 2 (DER Technology Classifications). We further distinguished energy efficiency (improved utilization of energy), which is not dispatchable, from load management (shifting or reduction in load to improve load factors), which is dispatchable and therefore compatible with DER*S.

Another panelist suggested that we clarify the differences between DER control types and how DER*S would fit into DER control schemes. The suggestion was to separate real-time closed loop control from scheduling and load dispatch. In the Preliminary Domain Analysis Report we described local DER real-time controls as fundamental operating

[2] As described in the Preliminary Domain Analysis Report

requirements that would not be part of the DER*S functionality. However, the panel suggested that we clearly define these different DER control types in order to eliminate any possible confusion on this issue. While we believe these are largely semantic issues, we agree that clarification is beneficial and the following descriptions were therefore added to the Domain Analysis Final Report.

- *Local Real-Time Control*
  These controls are for local regulation and operation DER equipment. For example, we described these controls as systems that provide safety features, grid interconnection and fundamental unit operating requirements such as fuel control, speed regulation, etc. This type of control will not be considered as part of the DER*S technology function.

- *Unit Scheduling*
  In the report we refer to this function as unit commitment and is the strategic scheduling of DER operation to maximize value. This is considered an important part of DER*S functionality.

- *Load Dispatch*
  This control function sets the best DER load point (generator output or load reduction) to maximize its operating value. Note that the DER unit must be both "scheduled" and available for load dispatch to take place. We consider this control function another important DER*S function.

3.2 Summary of Survey Responses

In addition to the general comments we received from the panel, we also requested that the panel answer a set of specific questions. Our questions and the panel's answers are summarized below.

1. Did the Preliminary Domain Analysis Report that you received adequately summarize the current situation relative to DER integration/use in the California competitive marketplace?

Yes, the report accurately characterizes the market dynamics, status of deregulation, competition, barriers and regulated aspects of the energy industry in California.

2. The report (see section 2.1) offered three basic DER / DER*S operating scenarios (Single Site/Asset w/o market participation, Multiple Asset w/o market participation, Multiple Asset w/ market participation). Please rank each operating scenario with a value of 0 – 10 in terms its applicability in the near, intermediate and long term using the following table (where 0 is not at all applicable and 10 is very applicable). *(Range of responses shown)*

Operating Scenario	**Near-Term (0 – 2 yrs)**	**Intermediate-Term (2 - 5 yrs)**	**Long-Term (+5 yrs)**
1. Single Site (w/o market participation)	*8-10*	*10*	*10*
2. Multiple Asset (w/o market participation)	*5-6*	*7-8*	*10*
3. Multiple Asset (w/ market participation)	*0-4*	*6-7*	*8-10*

3. Is there another operating scenario that you would envision in the near-, intermediate- or long-term? If so, please describe it briefly.

In general no, but gradual or incremental steps within each of the three scenarios is likely.

4. Who do you see as the most likely DER / DER*S owner/operator in the near-, intermediate- and long-term? (UDC, ESP, Building Owner/Operator, Other (please explain). Please check the appropriate boxes in the table below.

Owner/Operator	**Near-Term (0 – 2 yrs)**	**Intermediate-Term (2 - 5 yrs)**	**Long-Term (+5 yrs)**
Utility Distribution Company (UDC)	*X*	*X*	*X*
Energy Service Provider / Energy Service Co.	*X*	*X*	*X*
Building Owner/Operator		*X*	*X*
Other, ( )			

Note: Some respondents indicated a stronger probability for UDC ownership and operation. However, the panel also commented that UDC ownership would depend on the current CPUC DG OIR.

5. What do you see as the top three (3) barriers (if any) to the integration of DER assets into the California competitive marketplace? *(All responses are summarized here)*

Full installed cost of DER including capital, O&M, installation, back-up charges and CTC's.

Unrealized benefits of ancillary services that are possible through unbundled distribution rates.

Interconnection barriers including time, cost, and lack of regulatory standards/rules.

UDC ownership questions, issues and opposition.

Lack of streamlining of permitting and antiquated air quality paradigm regarding emission offsets.

6. What do you see as the top three (3) barriers (if any) to the application of the DER*S concept to the problem of scheduling DER operation? *(All responses are summarized here)*

Simultaneous cooperation and recognition of the DER benefits and operating standards for all market participants (ISO, PX, SC's, etc.)

Development of software and communication protocols that enables DER to be scheduled by SC for aggregation purposes, enabling arbitrage into PX/ISO markets.

Bundled distribution rates, which hide price sensitivities to time and area.

Cost of DER scheduling must be in-line with market's perceived value at most basic level.

7. In the Preliminary Domain Analysis Report we described a variety of DER technologies (see Table 3 in Section 4) that are potential candidates for DER*S control. Please list below the top three candidate DER technologies with a brief explanation for your selection. Understanding that DER technology is

application specific please provide a brief description of the application that is the basis for your response.

- ✓ ICE Gensets
  Have largest market penetration and are improving with new technology innovations.

- ✓ Small Gas Turbines
  For peaking use. Are cost effective and proven.

- ✓ Micro-Turbines and Fuel Cells
  Future potential may be huge depending on performance improvements and cost reductions.

8. Please list below the three DER technologies that are the least likely candidates for DER*S control along with a brief explanation of your selection. Understanding that DER technology is application specific please provide a brief description of the application that is the basis for your response.

- ✓ Energy Storage
  More applicable to straight power quality applications. Economics need to improve considerably, probably by significant increases in on-peak power costs to be viable.

- ✓ Renewable fuel generators including PV, wind and hydro.
  These are fuel hostage technologies and would likely be at maximum capacity, fuel permitting.

- ✓ Dish Stirling and Hybrid Fuel Cells
  Cost and size factors improvements needed before they become commercially attractive.

3.3 Panel Feedback Impact on DER*S

The panel produced a number of insights into the operation of the energy markets that will affect the DER*S functional design. As a result of panel feedback we made a number of changes and clarifications in the Domain Analysis Report, which are reflected in the Domain Analysis Final Report. For clarity, the major impacts resulting from the comments are summarized as below.

Load Management Capability

For the California (or any other deregulated market) to become truly competitive there must be a balance between supply-side pricing and customer choice on the demand-side. In other words, to stimulate supply-side competition the customer must have the ability to alter their demand in response to the market. This requirement produces an interesting effect in that local load reduction can have an equivalent or higher value than electric supply under certain conditions. DER*S should therefore be capable of managing a variety of demand-side management technologies in response to market pricing or other operational signals. The commercial implementation of DER*S must have the ability to reduce local load through direct load interruption or indirectly through climate or process set-point adjustments (e.g., raise commercial building thermostats to reduce a/c electric consumption or slowing down a industrial process to reduce electric demand) as well as through operation of on-site generation. We will be addressing these capabilities specifically during the DER*S agency design.

Compatibility with Existing DER Asset Markets

The panel emphasized the need for DER*S to be compatible with the large installed base of DER generator assets that currently exists in California. DER*S needs to be able to function with these existing assets since they will probably constitute the early DER*S market. This will require compatibility with both current generator control technologies as well as the more antiquated communication protocols (i.e., analog and RS-232C) in use on older equipment.

It is apparent from both the domain analysis and participant comments that DER*S must be compatible with a variety of DER technologies and manufacturers. This could necessitate a substantial DER*S interface development effort that would depend on obtaining communications protocol information from various manufacturers. One means of minimizing this development effort would be to "team" with an organization that has already developed interfaces for a variety of equipment and manufacturers. Teaming with a partner having experience is this area would allow DER*S development to focus on the scheduling and dispatch functions.

Near-Term Versus Long-Term DER*S Market Applications

To achieve commercial success, the DER*S core technology must not only be scalable in terms of number of DER*S assets, but must also be compatible with new DER technologies and implementations. For example, panelists indicated that future DER markets may include micro-grids where end use customers meet their on-site needs using one or more generators and/or storage devices operating independent of the grid. These micro-grids could eventually be interconnected with utility transmission and distribution system in a cooperative operating environment. DER*S should therefore be compatible with these new potential markets and the complex interaction with local versus grid-wide operations as well as with multiple price/operating signals. The DER*S agency must function in a transparent way in these complex scenarios to ensure that maximum benefits are generated.

While micro-grid operation in cooperation with the local UDC was identified as a potential future operating scenario, the panel was in agreement that local operation of equipment at a single site to offset energy and demand costs represented the most immediate market (our Operating Scenario 1). Use of DER*S to coordinate operations at multiple sites for purposes of aggregating load (with or without direct involvement in the competitive markets) was identified as the next most likely operating scenario. Several barriers exist to UDC involvement in the DER market, the most significant of which being regulatory constraints (i.e., UDC limitations to own generation assets), the fear that the UDC could exercise unfair market power relative to DER assets in their control[3], and the fear that widespread DER deployment will result in stranded T&D assets[4]. While these barriers make UDC involvement unlikely in the near-term it is likely that the benefits of UDC participation (i.e., improved power delivery reliability, reduced capital

[3] A UDC could use T&D "concerns" to favor operation of one DER asset (their own) over another.
[4] Extensive use of distributed generation could conceivably result in underutilized T&D assets, thus the fear of stranded assets.

expenditures for T&D, utilization of time and area dependent power costs, etc.) will encourage UDC involvement at some point in the future. Therefore, the DER*S design should be able to accommodate eventual UDC involvement.

Based on panel feedback it is apparent that we should focus our development and demonstration efforts on operating scenarios involving a single site with one or more DER assets and on applications involving DER*S operation to aggregate load from multiple sites.

California ISO Needs / Requirements

Direct involvement of DER*S in the bulk power markets via the Power Exchange was not seen as a likely scenario while possible involvement in the ancillary services markets either directly via an SC or indirectly via an ESCO was deemed a more likely long-term operating scenario. Direct participation of DER*S in the ancillary services markets would require compliance with ISO protocols pertaining to minimum portfolio size, DER asset location and metering. The ISO has indicated that the requirements are:

- A minimum portfolio size of 1 MW would be needed,
- All of the portfolio assets would need to be located within a single ISO zone[5].
- Each individual asset in the portfolio would need to have its own ISO certified meter installed, and
- The ISO would need to have the ability to override DER asset operation in the event of an emergency. This would have to be accomplished either through direct communication with DER*S or via an SC (which would in turn need to communicate with DER*S).

[5] This would facilitate intra-zone load balancing

4.0 Virtual Evaluation Group (VIREG)

We originally envisioned the virtual evaluation group (VIREG) as a subset of the much larger market participant group. VIREG participants would be selected for continued participation in the DER*S project based on their:

- ✓ Knowledge or experience in DER related technology important to DER*S project success,
- ✓ Interest in DER*S project success that may include future involvement in any commercialization effort(s).
- ✓ Expressed desire to continue participation beyond the market research effort(s).

The virtual evaluation group represents a pool of knowledge that we can draw upon during the course of the project. Unlike the market participant group, participants in the virtual evaluation group will only be asked to participate in areas of the project related to their backgrounds and interests. Each participant will receive periodic updates on project progress but requests for information (opinions, etc.) will be tailored to each of the VIREG participants. In this way, the DER*S project can benefit from the experience of the VIREG and can continue to cultivate potential commercialization partners without overly burdening the VIREG participants. Communications with the VIREG participants will consist of e-mail, conference calls and conventional mail.

4.1 VIREG Participants

While we had envisioned a relatively large base of market participants from which to choose VIREG participants, the reality was that market participants that had expended the effort to provide feedback did so because they had both an interest and desire to participate throughout the project. For this reason, the VIREG is comprised of all ten (10) of the market participants that provided comments/feedback. Table 2 contains brief descriptions of the companies and individuals that have agreed to participate in the virtual evaluation group.

Table 2 – Virtual Evaluation Group Participants

Company Name	Individual Name	Company / Organization Description
Allied Signal Power Systems, Inc.	Mark Skowronski	A subsidiary of AlliedSignal Inc that manufactures and markets a 75 kW turbogenerator (see http://www.alliedsignal.com)
California Independent System Operator	David Hawkins	Regional transmission system operator for California (see http://www.caiso.com)
Caterpillar, Inc.	Eric Wong	Large multi-national corporation, that manufactures a variety of distributed generation equipment consisting of both conventional reciprocating and gas turbine based (Solar Turbines Subsidiary) equipment. (see http:/www2.cat.com)
ENCORP, Inc.	Scott Castelaz	*EN*CORP, Inc. developed and markets the *en*power™ control systems and Virtual Power Plant™ software product lines. *En*power simplifies the task of managing and controlling a large number and wide variety of distributed resources (conventional, renewable and storage). (http://www.encorp.com)
Enflex, Corp.	David Wollins	EnFlex Corporation developed and currently markets the EnFlex® product line. EnFlex is a low cost networked information management, monitoring, and control gateway that resides at a remote facility and connects to a variety of intelligent devices within that facility. EnFlex can transport information over TCP/IP networks, the Internet, and corporate Intranets. (see http://www.enflex.net)
Lawrence Berkeley National Laboratory (LBNL)	Christopher Marnay	National laboratory involved in DOE sponsored project on US infrastructure reliability (CERTS) (see http://www.lbl.gov)
M-C POWER Inc.	Robert Petkus	Developer/manufacturer of molten carbonate fuel cells (see http://www.mcpower.com)
San Diego Regional Energy Office (SDREO)	Kurt Kammerer	The SD Regional Energy Office implement the energy policies of the San Diego Association of Governments. SDREO serves as an information clearinghouse for energy information and promotes collaborative public-private energy programs in the areas including Energy Efficiency, Renewable Energy, Energy Research & Development and Clean Fuel Vehicles. (see http://www.sdenergy.org)
San Diego Gas & Electric Co.	Victor Romero	San Diego based utility distribution company (see http://www.sdge.com)
Southern California Edison Co.	Carlos Martinez	Rosemead / Los Angeles based utility distribution company (see http://www.sce.com)

5.0 Potential Commercialization Partners

The current DER*S CEC PIER project provides for demonstration of the DER*S concept in a simulated operating environment and for development of demonstration software that will expedite transfer of DER*S technology to the private sector. Commercialization of the DER*S technology will require further development and associated funding to demonstrate DER*S in a "real-world" application and to develop the necessary interfaces and supporting documentation. This "product development" effort would be expedited from a scheduling, funding and marketing standpoint if a commercialization partner can be identified during the course of the project. Ideally, a commercialization partner identified during the CEC PIER project would provide some or all of the needed funding and expertise to assist in commercializing DER*S technology after completion of the current project.

With the exception of the national laboratory, LBNL, the CAISO and the SDREO, any of the remaining seven VIREG participants shown previously in Table 2 are "potential" commercialization partners. Each participant has valuable expertise in the energy industry and has expressed an interest in continued project participation. In the case of the UDC participants it is not clear if a regulated UDC could participate directly as a commercialization partner but an unregulated affiliate would certainly not have the same potential regulatory constraints.

It would be premature at this point in the project to limit our discussion of potential commercialization partners to the VIREG participants. Since we are still in the very early stages of DER*S product design and development it is difficult to fully convey the full potential of the project/product to potential commercialization partners. As the project progresses and DER*S becomes more fully defined it will be much easier to spark the interest of additional potential commercialization partners.

It would be more appropriate at this point to identify the most desirable traits of a potential commercialization partner. In general, a commercialization partner must provide more than just financial support. The following traits characterize a commercialization partner that would both enhance and accelerate DER*S commercialization and acceptance:

Existing Product or Technology That Enhances Potential DER*S Market Penetration

One of the quickest methods for DER*S to gain acceptance in the marketplace is for it to be seen as a logical extension of an existing product or technology. As a "value added" enhancement, DER*S would be able to "leap-frog" into the commercial marketplace with far less resistance. In the Domain Analysis Report we discussed how DER*S functionality would be limited to the schedule and dispatch functions with intrinsic DER functions such as safety, grid interconnect, unit synchronization, etc. handled by a separate control system. Therefore, a commercial partner that already produced and marketed systems capable of providing this type of intrinsic DER while using DER*S to achieve advanced dispatch and scheduling would be a logical choice. Developing a relationship with this type of product would also eliminate the need to develop multiple interfaces for a variety of equipment since this would have already been completed by the commercialization partner for their product. In this way, a single interface to the commercialization partner's product would provide immediate compatibility with any equipment already accommodated by the partner's product.

Existing Product Distribution / Support Infrastructure

A commercialization partner with an established product distribution and support infrastructure would greatly accelerate DER*S market acceptance. With any new technology, there is an initial period of "wait and see" while demonstration projects are identified and product savings potential is verified. The process of identifying and signing-up potential demonstration sites requires knowledge of potential sites and the responsible personnel. This type of information is often readily available to product distribution and support personnel.

Industry Name / Trademark Recognition

Association with a commercial partner that has already achieved industry name or trademark recognition would also shorten the time required for DER*S to achieve product acceptance.

Based on this list of desirable traits, ENCORP and EnFlex both initially stand out as potential commercialization partners. Both companies market products that could be enhanced by DER*S and both have achieved a level of recognition in the industry. However, large OEM's such as Allied Signal[6] and Caterpillar, could by virtue of their large distributed generator market share, provide significant marketing opportunities and should not be ruled out.

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[6] Allied Signal has recently merged with Honeywell. The combined company presents a significant opportunity for DER*S commercialization because of Allied Signal's distributed generator products and Honeywell's controls for energy management.

6.0 Conclusions

The original objectives of the market research effort were to: 1) establish a market participant evaluation group, 2) solicit feedback from the market participant group on key issues and questions that affect DER*S, 3) identify a select group of market participants and form a Virtual Evaluation Group (VIREG) to monitor and participate in the remainder of the project, and 4) identify potential DER*S commercialization partners. Relative to these objectives our market research efforts were very successful in that all of the stated objectives were achieved.

During the market research effort, we were able to form a diverse market participant group. We were overly optimistic regarding the number of market participants that would ultimately provide comments. Of the 111 potential market participants that we contacted via telephone or mail, we were able to obtain comments from 10 individuals. While the group was smaller than expected, the overall makeup of the group was both diverse and well suited to providing the feedback that we desired. Ultimately, the group provided valuable comments that resulted in changes to our Domain Analysis Report and will have a direct effect both the DER*S design and DER*S demonstration software. Market participant comments focused on:

- ✓ Our assessment of the California electric market(s),
- ✓ The compatibility/capabilities of DER*S with other DER technologies, and
- ✓ Projected DER*S market/operating scenarios

Overall, the market participant group found our description of the California electric market(s) to be both accurate and well written. Panel members understood the DER*S concept and confirmed the need for new scheduling and dispatch technologies to facilitate widespread DER operation and grid integration. Panel comments will enable us to refine the DER*S and demonstration software designs to better accommodate the needs of the market.

Based on the comments of the market participants, our initial assessment of how DER*S could be integrated into the California marketplace appeared to be pretty close to the mark. Their comments indicated that we were overly focused on the bulk power and ancillary services markets. We subsequently made changes that will provide for DER*S management of curtailable loads in response to either interruptible electric rates and/or the ancillary services markets. In addition, we now recognize the importance of DER*S operation at an individual site to directly offset facility utility costs without any need for involvement in either the bulk power or ancillary services markets.

In our Preliminary Domain Analysis Report we identified three basic DER*S operating scenarios. Market participant comments allowed us to refine these scenarios and to identify DER*S near- and long-term operating scenarios. In the near-term DER*S applications will likely focus on scheduling of DER operation at individual sites with little or no direct involvement in the electric markets. In the intermediate-term, DER*S operation could be extended to management of DER assets over multiple sites for purposes of load aggregation and load shaping. Multiple site operation could involve DER*S interaction with third parties such as ESCOs as well as involvement in the electric markets. Involvement in the bulk power markets, via the PX, was seen as unlikely given the relatively low price of bulk power. UDC involvement in both DER and DER*S operation is seen as a long-term development that is subject to the elimination of a number of market-based and regulatory barriers.

We were able to form the Virtual Evaluation Group (VIREG) from individuals that participated in our market participant group. We had initially envisioned a relatively large base of market participants from which to choose VIREG participants. What we found was that market participants that had provided comments did so because they had both an interest and desire to participate throughout the project. For this reason, the VIREG is comprised of all ten (10) of the market participants that provided comments/feedback.

Given the early stage of our project, it would have been premature to negotiate with, or otherwise engage, a commercial partner. However, we were able to identify the commercial partner traits that will maximize the benefit to the DER*S development and commercialization efforts. These traits call for a commercial partner that has:

- ✓ An existing product or technology that enhances potential DER*S market penetration,
- ✓ An existing product distribution / support infrastructure, and
- ✓ Industry Name / Trademark Recognition

In addition, we have identified potential partners having some or all of these traits. Some of these potential partners have agreed to participate in the VIREG. Other partners will be more approachable as the DER*S product design solidifies and we will therefore continue our efforts to identify additional potential partners as the project progresses.

Appendixes

Appendix A – Market Participant List

CEC - PIER Project
Market Participant List
(Status as of October 26, 1999)

Type	Name	Association	Position	Telephone Number	Fax Number	Email Address	Physical Address
DG Mfg	Mark Skowronski	Allied Signal Power Systems, Inc.				Mark.Skowronski@alliedsignal.com	2525 W. 190th Street Torrance, CA 90504-6099
ISO	Dave Hawkins	CAISO	Principal Engineer	(916) 351-4465	(916) 351-2310	dhawkins@caiso.com	151 Blue Ravine Road Folsom, CA 95630
DG Mfg	Eric Wong	Caterpillar	Product Consultant	(916) 498-3339	(916) 441-5449	erwong@worldnet.att.net	980 Ninth Street, Suite 2200 Sacramento, CA 95814
UDC	Carlos Martinez	Southern California Edison*	Manager	(626) 815-0512 (626) 815-0506	(626) 334-0793	jleeper@edisontec.com	6040 North Irwindale Avenue Irwindale, CA 91706
Ctrl Supplier	Scott Castalaz	Encorp	VP Marketing	(312) 945-3036		castelazsa@encorp.com	1512 South Prairie Ave, Suite F Chicago, IL 60605
Ctrl Supplier	David Wolins	EnFlex	VP Marketing	(510) 234-3244		dwolins@enflex.net	RICHMOND CA 94801
Researcher	Chris Marnay	Lawrence Berkeley National Laboratory	Staff Scientist	(510) 486 7028	(510) 486 7976	c_marnay@lbl.gov	90-4000 LBNL BERKELEY, CA 94720
DG Mfg	Robert Petkus	M-C Power Corp	Director Business Development				
Loc Gov	Kurt Kammerer	San Diego Regional Energy Office	Director	(619) 595-5630	(619) 595-5305	kkam@sandag.cog.ca.us	401 B Street, Suite 800 San Diego, CA 92101
UDC	Vic Romero	SDG&E		(619) 696-2000		VRomero@SDGE.com	8306 Century Park, CP52E San Diego, CA 92123-1593
Individuals listed below the line may still provide comments / feedback with participation in VIREG still a possibility.							
Researcher	Dr. Jack Brouwer	UCI/NFCRC	Assitant Director	(949) 824-1999 x221	(949) 824-7423	jb@nfcrc.uci.edu	University of California, Irvine Irvine, California 92697-3550
Utility	Dimitra Fotinatos, et. al.	SCE		(818) 302-8250			

* - Formerly with Edison Technology Solutions

Appendix B – Project Briefing Paper

1.0 Introduction

In September 1998, the California Energy Commission (CEC) awarded Alternative Energy Systems Consulting, Inc. (AESC) and it's principal subcontractor, Reticular Systems Inc. a contract for development and demonstration of an intelligent software agent based system for control and scheduling of distributed energy resources (e.g., distributed generation, energy storage, cogeneration, etc.) in a competitive energy market. This project, titled "Intelligent Software Agents for Control of Distributed Generation", was awarded under the second solicitation of the Public Interest Energy Research (PIER) Program (RFP 500-98-505).

Ultimately, an agent based controller/scheduler for distributed energy resources (DER) will only succeed in the marketplace if it meets the needs, experiences and standards of the industry. Therefore an important part of the proposed effort involves integration of industry requirements into the project/product requirements. To facilitate this effort, key players in the electric market will be identified, contacted and engaged with this project.

1.1 AESC Background

Alternative Energy Systems Consulting, Incorporated (AESC) is a closely held engineering and project development firm with offices in San Diego and Carlsbad, California. AESC was founded in 1994 to provide technical and management consulting support to utilities, large energy users and energy technology developers. AESC is focused on application of innovative technology in the rapidly changing energy markets. AESC's core personnel average 20 years of experience in the development and application of advanced computer processing systems and algorithms for power plant commitment/dispatch, diagnostics, large and small scale energy storage, energy theft detection, end-use control, and energy use optimization.

1.2 Project Description / Objectives

The proposed project is a research and development project involving the use of intelligent software agent technology in the energy industry. The proposed effort provides for development and demonstration of a Distributed Energy Resource Scheduler (DER*S) agency that assists the end-user in scheduling and controlling DER operations. Distributed Energy Resources are electrical generation or storage devices that, unlike large central generating plants, can be regionally located near loads and are often sited at customer facilities. Numerous studies[7] have shown that DER technology improves the reliability and cost effectiveness of electric distribution and transmission systems. These potential benefits combined with other competitive market forces will result in increased use of DER technology over traditional centralized generating stations relying on bulk transmission. This prototype agency of intelligent software agents will be suitable for use in scheduling/controlling one or more distributed energy resources.

[7] Specifically studies sponsored by Pacific Gas and Electric, the Electric Power Research Institute and others.

Briefing Paper for CEC/DER*S Project
Market Participant Candidates

An intelligent software agent is a software based device that acts on behalf of the user and has the ability to exploit knowledge, tolerate errors, reason with symbols, learn and reason in real time, and communicate in an appropriate language.

This project will facilitate insertion of intelligent software agent technology into the energy industry with its associated benefits. One of these benefits is to facilitate the coordinated scheduling of multiple distributed energy resource assets. Another is to reduce the level of expertise and oversight needed to own and operate distributed energy resources, which will allow greater participation by owners of distributed energy resources in the competitive energy industry.

The technical objectives of this project are to:

- ✓ Demonstrate, in a simulated operating environment, how a prototype network of intelligent software agents can coordinate and schedule one or more distributed energy resources.
- ✓ Develop a demonstration software package that will facilitate transfer of the project results into the private sector.

2.0 Background Information

2.1 Intelligent Software Agents

Intelligent software agents are a software abstraction. Here we mean abstraction in the same sense that objects, methods, procedures and subroutines are software abstractions. However, past research by AESC, Reticular Systems Inc. (Reticular) and others have shown that intelligent agents are a very powerful abstraction that facilitates development and construction of complex distributed information systems.

Software agents have a number of capabilities including the ability to monitor their own execution environment, communicate with other agents or the user and maintain some representation of their own internal mental state. Software agents are characterized by their ability to operate autonomously. This means that after an agent starts executing, no further interventions are required from the user. An autonomous agent is able to complete its task on its own.

While software agents are widely used in a variety of applications they are only now being applied to problems in the electric power industry. An intelligent software agent can contain significant amounts of expertise and be used in applications that require planning or learning capabilities. Agents are particularly useful in applications involving communications. One popular use of agents is information seeking and cataloging activities on the Internet. Agents can be used in applications where they learn about an individual user and modify their own behavior to suit the information-seeking needs of the user. Agents are particularly useful in applications where multiple agents can communicate and cooperate with other agents for solving a given problem. These agents can be physically located on the same computer or distributed in a variety of locations.

*2.2 DER*S Agency Description*

The DER*S will schedule the operation of one or more DER sites. DER*S operation will be driven by the site load requirements, the operating characteristics of the DER (i.e., generation only, co-generation, thermal energy storage, etc.) and market pricing for energy and ancillary services. The DER*S agency will consist of multiple agents, each assigned a specific task related to overall DER*S operation. For instance, one agent could monitor DER operation and performance characteristics while another agent could obtain information from external sources (i.e., weather, electric rates, etc.) that would be used by yet another agent tasked with data analysis and schedule generation. The DER*S agency configuration will be established during the project where the number and capabilities of the various agents will be determined based on the outcome of the domain analysis, market research analysis and task analysis efforts.

It can be assumed that each individual agent within the DER*S agency will operate autonomously and communicate as needed with human operators and other agents to achieve their individual goals and objectives. The content and protocols used to achieve these communications will also be determined as part of the development effort. DER*S communications with other DER*S sites as well as with the PX and/or another SC (Schedule Coordinator) may be necessary and as with other DER*S capabilities, will be decided in the domain analysis and market research efforts.

3.0 Energy Market Participant Feedback

Obtaining market feedback is a crucial element of this development project. Therefore, one of the primary objectives of the project's Domain Analysis and Market Research task is to identify and engage key players in the energy market. Realizing that that both interest level and time demand of potential participants will vary we will provide for participation at two levels. Additionally, we are acutely aware that the individuals that will be approached are already busy with their own pursuits. Therefore, we will make every attempt to minimize the level of effort for these individuals. Individual telephone conversations, conference calls and electronic mail will be used wherever possible to obtain the necessary feedback at the convenience of the participant.

As a potential market participants you have been provided with this DER*S Project Summary that includes; background information, project overview, technology descriptions, project objectives and initial topics for discussion. Feedback obtained in our initial discussions will be summarized in a Preliminary Domain Analysis Report along with the findings of AESC's other domain analysis activities. After review by the CEC PIER Program Manager, this report will be provided to you for your review and comment. It is anticipated that additional domain analysis activities will flow from your comments. Any additional findings will be incorporated into a Market Research Report and into the Final Domain Analysis Report. This process will also clarify the market's perception of the requirements and immediate needs for DER*S. Ultimately, the feedback obtained from market participants such as yourself will help us to more effectively direct the development effort and to incorporate DER*S features and functions that directly address the needs of the energy marketplace.

3.1 Virtual Evaluation Group Description

Evaluators who may have a higher level of interest will be asked to monitor the project's on-going progress. These evaluators will be organized into a "virtual" evaluation group that will collaborate primarily through electronic e-mail and periodic teleconferences. Subject areas for discussion include:

- ✓ On-going Situation Evaluation
- ✓ Challenges and Goals
- ✓ Identification of Needs
- ✓ Definition of Economic Benefits
- ✓ EnerAgent™ based DER*S Design Requirements
- ✓ Hardware and Networking Requirements
- ✓ User Interface Design
- ✓ Transaction Performance Measures and Goals
- ✓ Market Opportunity & Risk Assessment
- ✓ Asset Evaluation, Commitment and Dispatch Methods
- ✓ External Information Source Identification

It is anticipated that the amount of time that these cooperative participants can spend on reviewing and commenting on DER*S aspects will be limited. Therefore, the first order of business for the virtual evaluation group will be to identify and prioritize the subject areas for review. This will also allow us to match the interests and backgrounds of individual participants with the various aspects of the project. Some individuals in the evaluation group will undoubtedly have an interest in specific aspects (i.e., communications protocols, market interaction, etc.) of the project with little interest in other aspects. Therefore, we will only ask participants to provide feedback on the project areas that are both relevant and of interest to them.

3.2 Potential Commercial Partner

Identifying potential commercial partners is another reason for engaging market participants in project activities at an early stage. If identified early on, the partner is expected to actively participate in the prototype development effort and to provide early input on the system design. Involvement at an early stage will facilitate product commercialization at the conclusion of this development effort.

4.0 Initial Topics of Discussion

The following issues / topics have been identified as potential topics for discussion.

4.1 What types and quantities of distributed energy resource equipment are and will be deployed?

While detailed market analysis and forecasting is beyond the scope of this project, we believe that a reasonably accurate assessment of existing and future DER applications can be made. Existing DER would include but would not be limited to; emergency/backup generators, cogeneration plants, renewable fuel generators, and on-site peak shaving generators. Future DER applications would include expansion for the existing applications plus; arbitrage generators, residential DER, electric energy storage, and UDC operated DER. Pending regulatory decisions may shape, to great extent, the emerging DER application market. For this project we are most interested in developing likely application scenarios and using them as models to determine benefits from implementation of the DER*S technology.

4.2 How does a distributed energy resource provide benefit to the end-user in both a regulated and competitive environment?

This question attempts to establish the baseline benefits for DER owners and customers ***without*** DER*S. Another way of asking this question would be: how will DER assets be controlled and what benefits are derived from this type of DER control? For example, backup generators are common equipment for many institutional, commercial and industrial customers. Their operation is typically controlled by loss of line, voltage or frequency abnormalities. We want to establish how these benefits, such as power supply reliability, are derived and limited by existing control.

4.3 Does the use of intelligent software agents provide additional opportunities for distributed energy resource savings?

We expect intelligent software agents to enable additional benefits beyond what conventional control of DER equipment can provide. Here we are asking the panel to validate the additional benefits by using intelligent software agents for DER coordination and scheduling. This will require thinking about these benefits in terms of the future electric market opportunities.

4.4 What other entities must a distributed energy resource communicate and/or interconnect with in order to operate effectively?

If DER*S is to increase benefit opportunity it probably will interact and communicate with other entities to derive these added benefits. For example, one of these entities may be the utility distribution company (UDC). DER*S may interact with UDC operations so that peak feeder loads may be controlled so that deferred utility capital investment may be realized. Other entities may include; the ISO, CalPX, other DER's and customer energy management controls.

4.5 What are the market factors that impact the viability of advanced control of DER?

We anticipate that the viability of DER*S will be limited by a number of market factors. One possible limitation is the speed of deployment of electric distribution automation. Without a robust automated distribution system, it will be difficult for the DER*S benefits from UDC operations to be realized. Other market factors such as low cost tolerances for DER control may also limit DER sophistication and functionality. We are interested, in asking these questions, in identifying all the significant market factors that limit the deployment and affect the design of the DER*S technology.

4.6 What is the current state-of-the-art in distributed energy resource control equipment?

Here we are interested in identifying available and future DER control equipment and their functional designs.

4.7 What are the technological barriers to successfully implementing distributed energy resource control with intelligent agent technology?

Here we are asking the panel to help us determine the technical obstacles that we must be aware of as the DER*S development project progresses. What are the difficulties interfacing with DER controls, communicating with utility distribution equipment, receiving electric price signals, etc?

Appendix C – Preliminary Domain Analysis Report

Appendix D – Market Participant Survey

Market Participant Questions / Issues

1. Did the Preliminary Domain Analysis Report that you received adequately summarize the current situation relative to DER integration/use in the California competitive marketplace?

   If No, then please summarize the most significant deficiencies so that we may provide a more complete description in the Final Domain Analysis Report.

2. The report (see section 2.1) offered three basic DER / DER*S operating scenarios (Single Site/Asset w/o market participation, Multiple Asset w/o market participation, Multiple Asset w/ market participation). Please rank each operating scenario with a value of 0 – 10 in terms its applicability in the near, intermediate and long term using the following table (where 0 is not at all applicable and 10 is very applicable).

Operating Scenario	**Near-Term** (0 – 2 yrs)	**Intermediate-Term** (2 - 5 yrs)	**Long-Term** (+5 yrs)
1. Single Site (w/o market participation)			
2. Multiple Asset (w/o market participation)			
3. Multiple Asset (w/ market participation)			

3. Is there another operating scenario that you would envision in the near-, intermediate- or long-term? If so, please describe it briefly.

4. Who do you see as the most likely DER / DER*S owner/operator in the near-, intermediate- and long-term? (UDC, ESP, Building Owner/Operator, Other (please explain). Please check the appropriate boxes in the table below.

Owner/Operator	**Near-Term** (0 – 2 yrs)	**Intermediate-Term** (2 - 5 yrs)	**Long-Term** (+5 yrs)
Utility Distribution Company (UDC)			
Energy Service Provider / Energy Service Co.			
Building Owner/Operator			
Other, ( )			

5. What do you see as the top three (3) barriers (if any) to the integration of DER assets into the California competitive marketplace?

   I.

   II.

   III.

6. What do you see as the top three (3) barriers (if any) to the application of the DER*S concept to the problem of scheduling DER operation?

   I.

   II.

   III.

7. In the Preliminary Domain Analysis Report we described a variety of DER technologies (see Table 3 in Section 4) that are potential candidates for DER*S control. Please list below the top three candidate DER technologies with a brief explanation for your selection. Understanding that DER technology is application specific please provide a brief description of the application that is the basis for your response.

   I.

   II.

   III.

8. Please list below the three DER technologies that are the least likely candidates for DER*S control along with a brief explanation of your selection. Understanding that DER technology is application specific please provide a brief description of the application that is the basis for your response.

   I.

   II.

   III.

Appendix E – White Paper – Interconnection and Controls for Reliable, Large Scale Integration of Distributed Energy Resources[8]

[8] White paper by the Consortium for Electric Reliability Technology Solutions titled Interconnection and Controls for Reliable, Large Scale Integration of Distributed Energy Resources.

Appendix II
Final Domain Analysis Report

CEC-PIER Project 500-98-040
Intelligent Software Agents for Control and Scheduling of Distributed Generation

Domain Analysis
Final Report

Prepared for:

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September 29, 1999

LEGAL NOTICE

Executive Summary

Alternative Energy Systems Consulting, Inc. (AESC) is currently under contract to the California Energy Commission (CEC) for development and demonstration of a scheduler / controller of Distributed Energy Resources (DER) that will operate in the California competitive energy marketplace. Specifically, the CEC-PIER project titled, "Intelligent Software Agents for Control & Scheduling of Distributed Generation", provides funding to demonstrate the viability of scheduling and/or dispatching one or more distributed energy resources using intelligent software agents. Where an intelligent agent is a software-based device that acts on behalf of the user and has the ability to exploit knowledge, tolerate errors, reason with symbols, learn and reason in real time, and communicate with other agents or entities. Multiple agents acting independently, in a cooperative fashion, are called an agency. For this project we will develop and test a prototype agency called the Distributed Energy Resource Scheduler (DER*S).

The preliminary domain analysis was the first task in the CEC-PIER project. In this task AESC analyzed the California energy industry in order to characterize the potential DER*S markets (e.g., end-users/potential owners, benefits and capabilities). The results of this analysis effort were summarized in the Preliminary Domain Analysis Report. During the preliminary domain analysis effort AESC identified basic DER*S operating scenarios based on analysis of the current energy marketplace in California, potential DER technologies and their potential benefits. In a related effort, AESC formed a market participant evaluation group comprised of key individuals and companies that operate in, or have knowledge of, the competitive energy industry and/or distributed energy resources. The market participant evaluation group provided vital feedback on key issues and questions raised in the preliminary domain analysis. Specifically, the market participant group was used to prioritize the potential DER*S markets. Results of this market research effort are summarized in the Market Research Report. Ultimately, our objective was to characterize the DER*S operating environment, or domain, for the most likely DER*S markets.

We concluded from our analysis that DER*S is only applicable to DER equipment that can be dispatched. Non-dispatchable technologies, such as wind, solar, and energy efficiency, are not compatible with DER*S because their production output is not controllable. However, in some DER technologies, the addition of energy storage *can* provide dispatching capability. Other DER technologies such as ultracapacitors and SMES provide short bursts (i.e., milliseconds) of electric energy to improve power quality. Although dispatchable, these technologies are triggered by power quality events and do not affect the aggregate value of electric energy. Curtailable loads are dispatchable but to varying degrees depending on the type of load involved. For example, remote control of cycling of residential or small commercial air conditioners is a dispatchable resource that could be bid into the ancillary services market as non-spinning reserve (available within 10 minutes). Loads (i.e., process loads, etc.) requiring additional time could still be classified and scheduled/dispatched as replacement reserves (available within 60 minutes).

Entities that could benefit from DER*S operation are envisioned as building owners/operators, ESCOs (or other load aggregator) or Utility Distribution Companies (UDC). A building owner / operator could benefit by using DER scheduling to lower overall energy costs and increase power supply reliability. An ESCO (or other load aggregator) could use DER*S for bundling of customer on-site DER services with power and fuel contracts to increase customer value and improve contract margins. DER*S could also enable building owners/operators and ESCOs to bid into one or more of the California energy or ancillary services markets. UDC participation in DER*S applications may be based on a connection between potential DER benefits and UDC Performance Based Ratemaking (PBR) mechanisms. Several studies have identified power delivery cost and performance benefits derived from DER installations and past studies by the Electric Power Research Institute (EPRI), Pacific Gas and Electric (PG&E) and others have identified potential UDC benefits from DER that include; capital deferral, reduced energy loss and improved reliability. Direct ownership of DER assets by Utility Distribution Companies (UDC) continues to be the subject of debate. Therefore in the near-term it is unlikely that UDCs will own or operate DER assets, however this could change as the marketplace continues to evolve.

The DER*S operating environment can vary significantly in terms of the number and types of entities that are involved. Based on our assessment of the California marketplace we believe that there are three basic DER*S operating scenarios, each with a differing level of complexity. In the first scenario, DER*S operates one or more DER assets at a single site to minimize site energy costs. DER*S will monitor site load and DER performance and access weather data via the Internet in order to predict site loads. In addition, or in lieu of this information, DER*S may receive pricing signal(s) from the local UDC depending on the applicable electric rate. Electricity and possibly for natural gas prices (depending on the DER asset involved) could also be accessed via the Internet as needed. In this scenario, DER*S operates the DER asset to reduce on-site loads and associated costs without any direct involvement in the various energy and demand markets (CalPX or CAISO). Note that this operating scenario could also apply to DER*S scheduling/dispatching of DER assets installed at a substation with UDC operation / ownership of DER*S (if UDC ownership/operation of DER assets is permitted).

The second scenario provides for DER*S aggregation of multiple assets without direct involvement in any of the competitive markets. Under this operating scenario DER*S aggregates load or otherwise coordinates operation of DER assets at multiple sites. This would allow sites/businesses to respond to interruptible rates or could provide an ESCO with load shaping capabilities. The DER*S at each individual site would have knowledge of site load and DER asset performance and would “represent” its site’s interests in responding to UDC pricing signals (if provided) or ESCO load shaping constraints. As with the single site operating scenario, DER*S could access the Internet for weather and possibly for electricity and natural gas prices depending on the DER asset involved. In this scenario, DER*S operates to reduce site energy costs but with the added complexity of operating in conjunction with other DER*S equipped sites. In this scenario there is no direct involvement with external competitive markets.

The third operating scenario involves both aggregation of multiple assets and participation in one or more of the competitive markets. This operating scenario is similar to the second scenario in that multiple sites are involved. However, in this case DER*S is responding to, and participating in, one or more of the competitive markets operated by either the CalPX or CAISO. Market participation could be either via the CalPX or another Scheduling Coordinator (SC). In this scenario, the DER*S agents would have to balance site loads and costs against the potential return of bidding into one or more of the competitive markets. For instance, if high ancillary service pricing is predicted then bidding of standby generator capacity or curtailable load(s) could be justified.

The market participant group identified the first two operating scenarios as the most likely to occur in the near-term and intermediate-terms. Although in both cases, UDC involvement in the form of ownership or operation of DER/DER*S assets is uncertain. While DER*S could enable direct involvement in California energy and demand markets (operating scenario 3) this is seen as unlikely in the near-term. This type of involvement is seen as a more long term operating scenario as the California market continues to evolve and DER integration into the California marketplace progresses.

Based on the three basic operating scenarios and the potential DER assets involved we have identified the most likely DER*S capabilities, which can be divided into two basic categories. The first category contains essential capabilities and the second contains capabilities that could improve product performance or market acceptance (e.g., “bells and whistles”). The seven basic capabilities considered essential to DER*S product viability are:

- ❖ Monitor and Forecast DER Asset Performance / Output
- ❖ Monitor and Forecast Site Load (energy and demand) Requirements
- ❖ Monitor and Forecast Relevant Market Pricing
- ❖ Schedule DER Operation to Maximize Economic Benefit
- ❖ Graphical User Interface (GUI)
- ❖ Data Storage & Retrieval
- ❖ Communicate with External Entities (i.e., Internet, DER controls, etc.)

Additional capabilities that would improve DER*S product performance or market acceptance are primarily related to automation of various aspects of DER*S-DER operations. . These additional capabilities are:

- ❖ Automatic Retrieval of Routine Data
- ❖ Direct Connection and Dispatch of DER Asset(s)
- ❖ Diagnose Building and/or DER Performance Problems
- ❖ Direct Communication and Data Transfer with Affected Agencies (if applicable)
- ❖ Automatic Verification / Resolution of Settlement Statements (if applicable)

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1.0 Introduction

This domain analysis effort is the first task in a California Energy Commission PIER research and development project titled, "Intelligent Software Agents for Control & Scheduling of Distributed Generation". The overall project objective is to demonstrate the viability of using intelligent software agents for scheduling and dispatching of one or more distributed energy resources (e.g., distributed generation, energy storage, cogeneration, etc.) in a competitive market. An intelligent agent is a software-based device that acts on behalf of the user and has the ability to exploit knowledge, tolerate errors, reason with symbols, learn and reason in real time, and communicate in an appropriate language. Multiple agents operating in conjunction, as an agency, can achieve goals/objectives that would not be otherwise achievable by a single agent. For this project we will develop and test a prototype agency called the Distributed Energy Resource Scheduler (DER*S) that will schedule operation of distributed energy resource (DER) equipment in a competitive energy market.

The purpose of the domain analysis effort was to analyze the California energy industry in order to characterize the potential markets (e.g., end-users/potential owners, benefits and capabilities) for DER*S. In a related effort, we established a market participant evaluation group comprised of key individuals and companies that operate in, or have knowledge of, the competitive energy industry and/or distributed energy resources. This market participant evaluation group provided vital feedback on key issues and questions. The overall domain analysis effort was an iterative effort where information gained from the market evaluation group raised additional questions requiring additional analysis of the domain. Ultimately, it was our objective to characterize the DER*S operating environment, or domain, for the most likely DER*S markets.

Key questions that were examined in the domain analysis include:

- What types and quantities of distributed energy resource equipment are and will be deployed?
- How does a distributed energy resource provide benefit to the end-user in a competitive environment?
- Does use of intelligent software agents provide additional opportunities for distributed energy resource savings? (i.e., aggregation, etc.)
- What other entities must a distributed energy resource communicate and/or interconnect with in order to operate effectively?
- Are there market factors that impact the commercial viability of advanced control (i.e., infrastructure considerations, rates/pricing of energy and ancillary services, utility distribution company ownership of distributed energy resources, etc.)?
- What is the current state-of-the-art in distributed energy resource control equipment?

- What are the technological barriers to successfully implementing distributed energy resource scheduler using intelligent agent technology?

Ultimately, the information gained in this effort will be used to set broad goals and objectives for the DER*S prototype product.

To fully cover the domain of interest we will first summarize potential DER*S operating scenarios and associated capabilities showing how DER*S could be integrated into the competitive marketplace. This will be followed by a discussion of the California competitive market as it currently exists as well as the basics of DER technology. A discussion of how DER, and potentially DER*S, achieves benefits for a variety of market participants is also provided.

2.0 DER*S Description

For purposes of this domain analysis we will think of DER*S as a "black box" with capabilities to be defined by the target marketplace. Our discussion will therefore focus on potential operating scenarios and the associated DER*S capabilities necessary for each.

2.1 DER*S Operating Scenarios

The DER*S operating environment can vary significantly in terms of the number and types of entities that are involved. Our analysis (see DER technology discussion) leads us to believe that there are three basic operating scenarios for DER*S in a competitive marketplace, each with a differing level of complexity. Our discussion of DER*S operation will therefore be divided into three basic operating scenarios. In the first scenario, DER*S operates at a single site to minimize site energy costs. The second scenario provides for DER*S aggregation of multiple assets without direct involvement in any of the competitive markets. The third scenario involves both aggregation of multiple assets and participation in one or more of the competitive markets.

Single Site Operation

In this first and simplest operating scenario, DER*S operates one or more DER assets at a single site to minimize energy costs. In this configuration (see Figure 1), DER*S will monitor site load and DER performance. DER*S will access weather data via the Internet in order to predict site loads. Depending on the DER asset involved DER*S may also access the Internet for electricity and possibly for natural gas prices. DER*S may receive pricing signal(s) from the local UDC depending on the applicable electric rate, which would in turn affect the decision process and the associated data requirements.

In this scenario, DER*S operates the DER asset to reduce on-site loads and associated costs without any direct involvement in the various energy and demand markets. No direct contact is therefore required with either the CalPX or CAISO. Note that this configuration could also apply to DER installation at a substation with UDC operation / ownership (if UDC ownership or operation of DER assets were allowed).

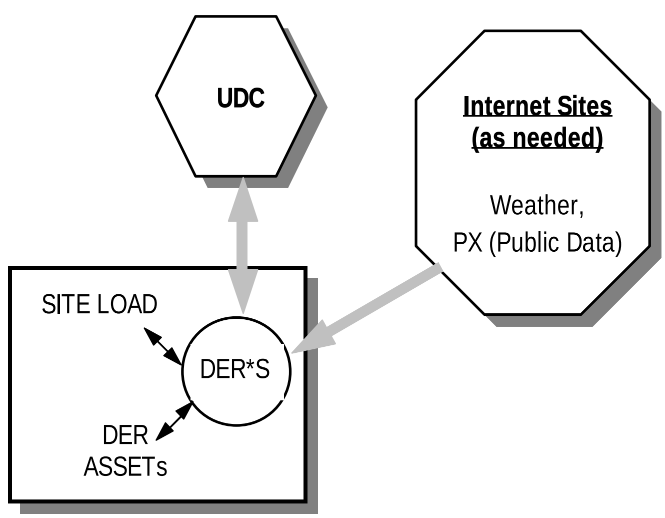

Figure 1 – Single Site DER*S Operation

Given the simplicity of this operating scenario one could argue that there is little use for an agent-based scheduler employing distributed processing. The possible exception would be sites with multiple DER assets since individual DER assets could conceivably be represented by individual by agents.

Multiple Asset Operation – No Market Participation

Under this operating scenario (see Figure 2) DER*S aggregates load or otherwise coordinates operation of DER assets at multiple sites. This would allow sites/businesses to respond to interruptible rates while still maintaining critical processes. The DER*S at each individual site would have knowledge of site load (size, priority of served loads, etc.) and DER asset performance. Each DER*S would "represent" its site's interests in responding to UDC pricing signals as a group. As with the single site operating scenario, DER*S could access the Internet for weather and possibly for electricity and natural gas prices depending on the DER asset involved.

In this scenario, DER*S operates to reduce site energy costs but with the added complexity of operating in conjunction with other DER*S equipped sites. In the case of the interruptible rate scenario, each DER*S could "bid" its load reduction amount into a pseudo-market and would act according to the outcome. Note that the figure shows a single connection to the UDC with this information passed to the remaining DER*S. In another operating scenario, DER*S equipped sites could operate cooperatively to provide aggregated load shaping for an ESCO. In that event, the ESCO could send out a pseudo-pricing signal similar to a UDC or even broadcast a load reduction goal to the DER*S agency for implementation. The DER*S agency would then cooperatively determine the best course of action that both meets the ESCO and individual site needs.

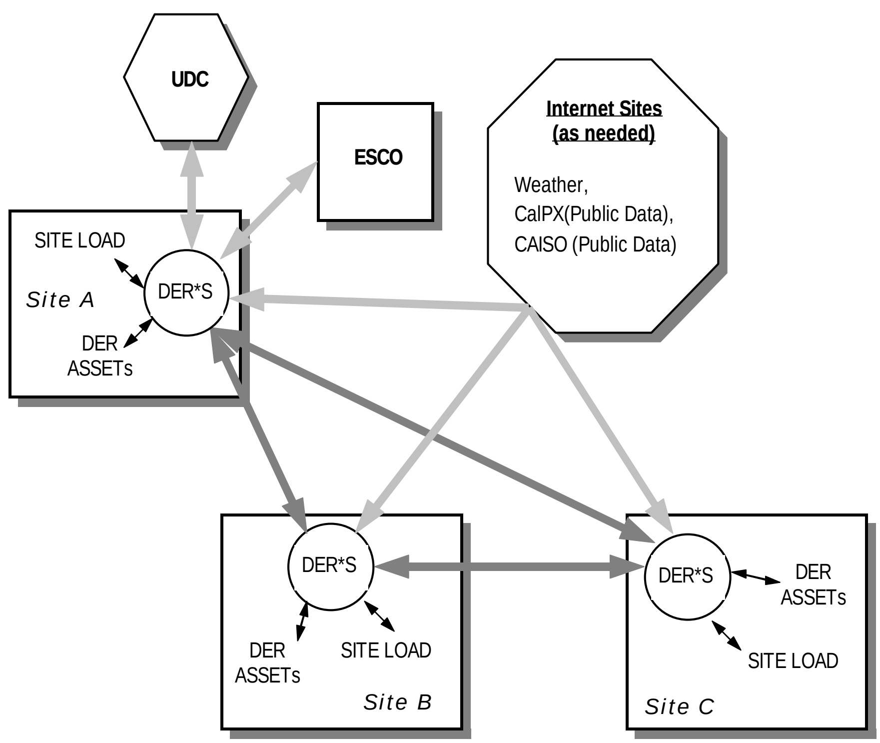

Figure 2 – DER*S Multiple Sites – No Market Participation

As with the previous scenario there is no direct involvement in the competitive markets since DER*S is responding to UDC rates and/or other pricing signals. No direct contact is therefore required with either the CalPX or CAISO. Note that this configuration could also apply to DER installations at multiple substations with UDC operation in response to distribution system loads (if UDC ownership or operation of DER assets were allowed).

Multiple Asset Operation – Direct Market Participation

The third operating scenario (see Figure 3) is similar to the second scenario in that multiple sites are involved. However, in this case DER*S is responding to, and participating in, one or more of the competitive markets operated by either the CalPX or CAISO. The figure arbitrarily shows three DER*S equipped sites, each with a DER*S

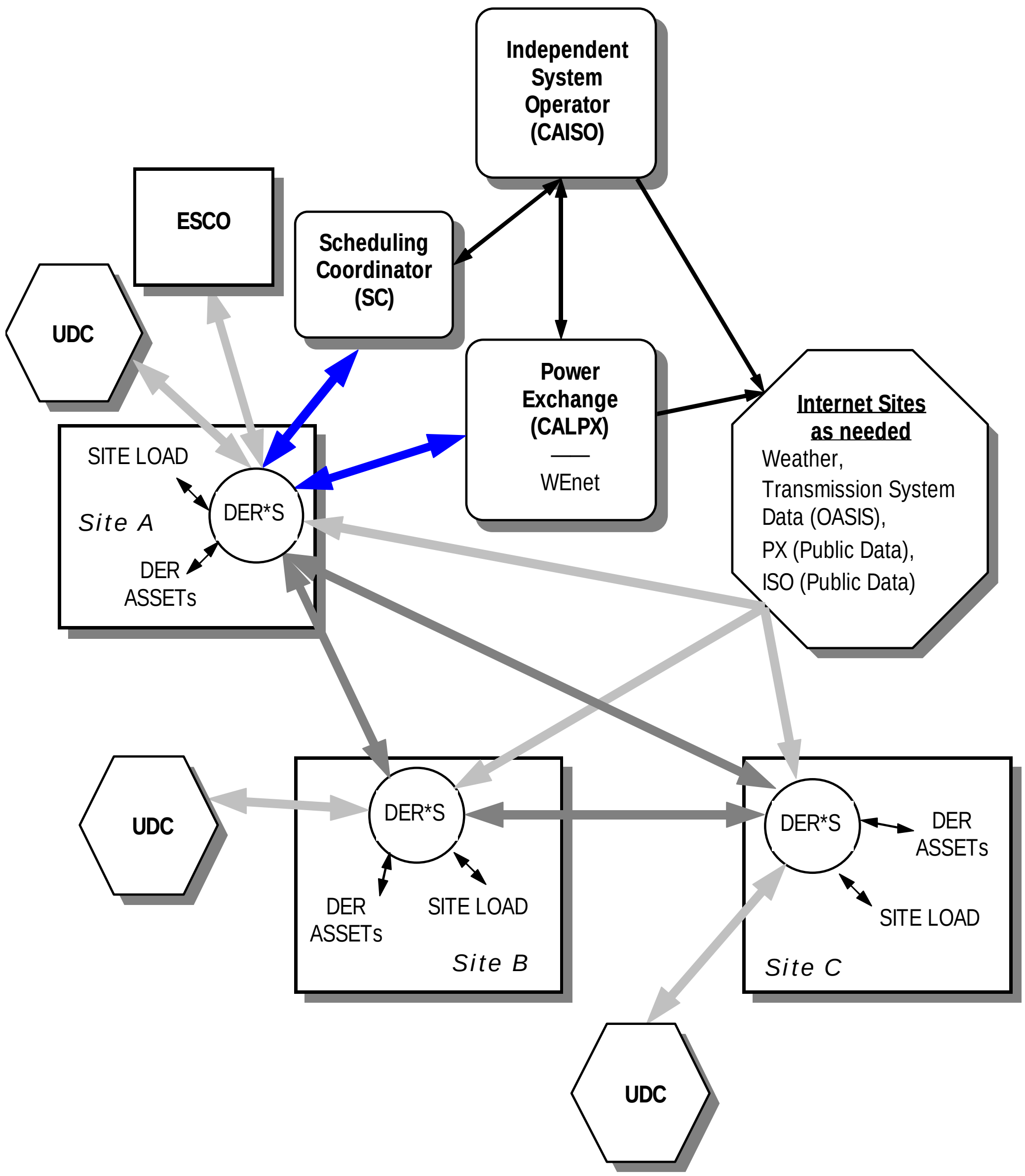

Figure 3 – DER*S Multiple Sites – Direct Market Participation

connected internally to site load information and one or more DER assets. External connections with various Internet sites, other DER*S equipped sites, the CalPX, the local UDC, an ESCO and/or a schedule coordinator are all possible. Market participation could be either via the CalPX, another SC indirectly via an ESCO.

In this scenario, the DER*S agents would have to balance site loads and costs against the potential return of bidding into one or more of the competitive markets. For instance, if high ancillary service pricing is predicted then bidding of standby generator capacity or curtailable load(s) could be justified. At this point, it appears unlikely that DER generation assets would bid into the bulk power market (CalPX) since generating power to offset local energy use (at the higher local rate) would provide greater benefit. However, bidding into one or more of the ancillary services (AS) markets may be justified in light of the volatility of these markets and the potential for high short term returns.

2.2 DER*S Capabilities

While it is not yet possible to fully define DER*S capabilities it is possible to infer some of the most likely capabilities based on our three basic operating scenarios. These capabilities can be divided into two categories where the first category contains essential capabilities and the second contains capabilities that could improve product performance or market acceptance (e.g., “bells and whistles”).

Basic DER*S Capabilities

The seven basic capabilities considered essential to DER*S product viability are:

- Monitor and Forecast DER Asset Performance / Output
- Monitor and Forecast Site Load (energy and demand) Requirements
- Monitor and Forecast Relevant Market Pricing
- Schedule DER Operation to Maximize Economic Benefit
- Graphical User Interface (GUI)
- Data Storage & Retrieval
- Communicate with External Entities (i.e., Internet, DER controls, etc.)

Additional DER*S Capabilities

Additional capabilities that would improve DER*S product performance or market acceptance are primarily related to automation of various aspects of DER*S-DER operations. . These additional capabilities are:

- Automatic Retrieval of Routine Data
- Direct Connection and Dispatch of DER Asset(s)
- Diagnose Building and/or DER Performance Problems
- Direct Communication and Data Transfer with Affected Agencies (if applicable)
- Automatic Verification / Resolution of Settlement Statements (if applicable)

3.0 California's Competitive Market[1]

The competitive market in California began operating on April 1, 1998. The California electricity market comprises approximately 10% of the total U.S. market representing roughly $22 billion in annual revenues and 246,000 GWh of annual energy consumption. About 70% of the total energy consumed in the California electricity market is provided by the three major investor-owned utilities (IOUs) (Southern California Edison, Pacific Gas & Electric, and San Diego Gas & Electric). The remainder is consumed in the service territories of municipal utilities and government entities.

3.1 Market Structure

Figure 4 shows the basic structure of the California competitive market(s) and the various entities involved in the production, distribution and use of energy in California. Additional information on the various market participants is provided in the following sections.

Customers (C)

Customers are end-users of energy in California and may be commercial, industrial or residential. All customers may choose direct access via a local utility or energy service provider (ESP) / Non-utility retailer. Energy service providers may aggregate customer loads to lower purchased power prices and transactions costs.

Generator / Supplier (G)

Generators / suppliers of power may bid into the spot market maintained by the California Power Exchange (CalPX) or schedule power deliveries directly with the California Independent System Operator (CAISO) using a Scheduling Coordinator. Using a Scheduling Coordinator, generators may also bid ancillary services into the California ISO or self-provide these services. Suppliers may have contracts with retailers and respond to CAISO instructions for unit operation provided by the Scheduling Coordinator or directly by the CAISO (depending on the nature of the service provided).

Retailer / Energy Service Provider (ESP)

Non-utility retailers / Energy Service Providers purchase power for, and market power to retail customers. ESPs may serve as demand aggregators for retail loads and schedule load and generation with the CAISO through a Scheduling Coordinator or the CalPX.

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[1] This description is based on information provided in a recent report by the Market Monitoring Committee Of the California Power Exchange titled "Report on Market Issues in the California Power Exchange Energy Markets" by Roger E. Bohn et al. This report was prepared for the Federal Energy Regulatory Commission and issued on August 17, 1998.

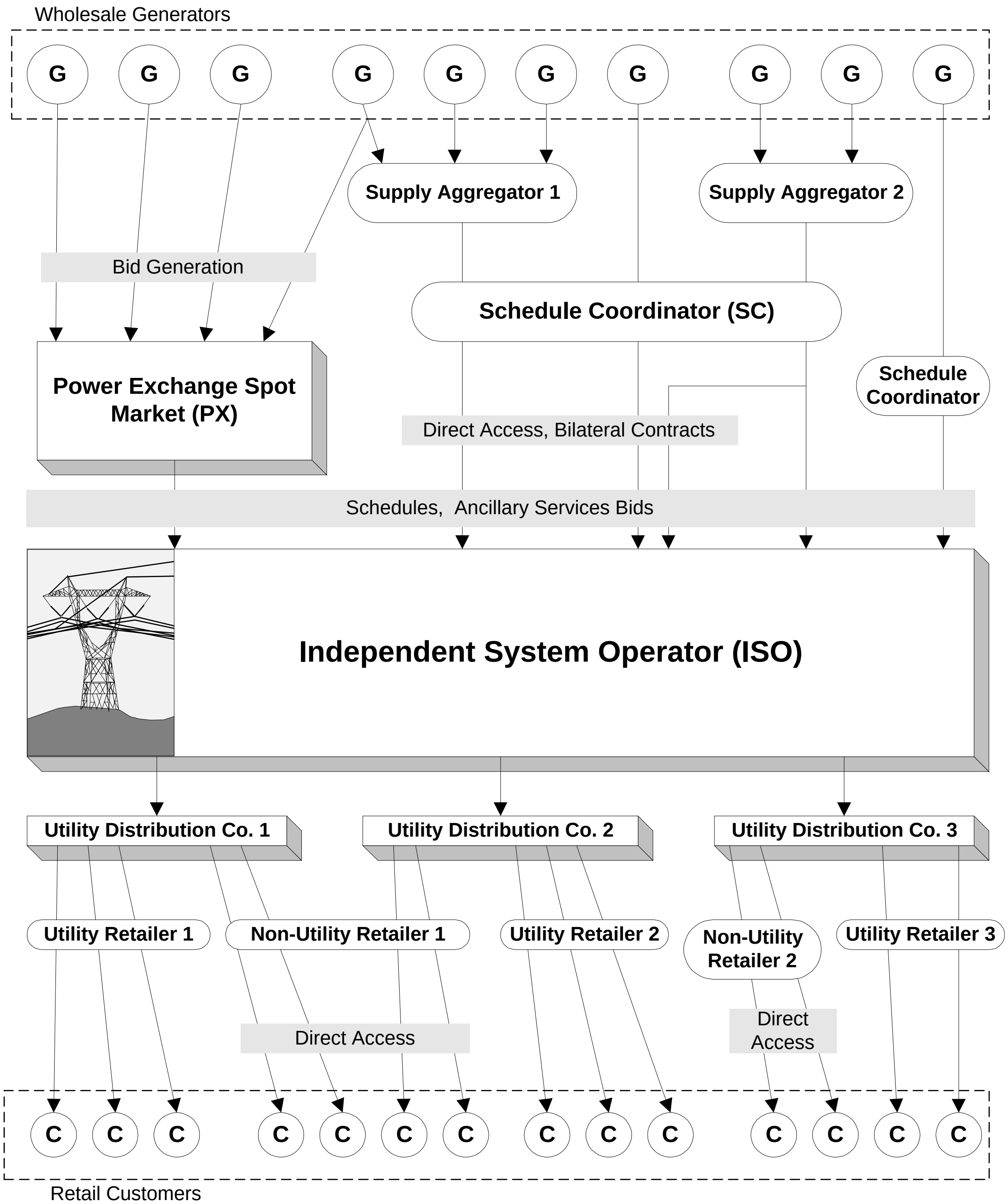

Figure 4 - California Competitive Market Structure

Scheduling Coordinator (SC)

SCs submit balanced schedules and provide settlement ready meter data to the CAISO. SCs settle with generators and retailers, the CalPX and the CAISO; maintain a year round twenty-four hour scheduling center and provides CAISO operating instructions to generators and retailers, transfer schedules in and out of the CalPX.

Utility Distribution Company (UDC)

The Utility Distribution Company maintains the electric distribution system within their individual service areas. UDCs provide distribution service to all customers within their service territory and are responsible for the sale of energy to all customers not classified as “direct access” customers (e.g., customers that contract with Retailers / Energy Service Providers). UDCs must supply all of their energy needs (sell generation into and purchase energy from) via the spot market maintained by the CalPX.

California Power Exchange (CalPX)

The California Power Exchange is a non-profit corporation that was formed for the primary purpose of providing a non-discriminatory, competitive energy auction open to all suppliers and spot-market purchases. The CalPX manages two forward energy markets (day-ahead, day-of[2]) and one demand market (block forward). Since the market opened, the CalPX has accounted for roughly 88% of the restructured California electric energy market. CalPX participants number approximately 45 and include UDCs, Federal and municipal entities, independent power producers, and ESPs, from both inside and outside of California. Based on the outcome of its day-ahead energy market the CalPX determines the Market Clearing Price (MCP) at which energy is bought and sold (excluding transmission congestion costs).

In addition to managing the forward markets the CalPX acts as an SC and submits balanced schedules to the CAISO for all of its participants and may act on behalf of its participants for submittal of bids into the CAISO ancillary services and imbalance energy markets. As a SC the CalPX performs settlement functions with the CAISO and CalPX participants, and reports usage to the CAISO for settlement purposes.

California Independent System Operator (CAISO)

The California Independent System Operator is a non-profit corporation tasked with maintaining a secure and reliable power supply in California. The CAISO controls the dispatch of generation and manages the reliability of the transmission grid while providing open access to the transmission system assets. The CAISO coordinates day-ahead, hour-ahead / day-of schedules and performs real-time balancing of load and generation using assets obtained in its ancillary services, imbalance energy and

[2] The CalPX originally maintained an hour-ahead market that was subsequently changed from 24 hourly auctions to 4 daily auctions with a corresponding name change from Hour-ahead to the Day-of market.

transmission congestion management markets. The CAISO does not own transmissions assets but does administer congestion management protocols for the transmission grid.

In addition to the Ancillary Service markets, which operate through an hourly market-clearing auction process, the CAISO also is responsible for acquiring Voltage Support/Reactive Supply and Black Start capability, which it procures through a longer term contracting process.

3.2 Restructured Market Operation

The restructured market continues to evolve as experience is gained and lessons are learned. It should be noted that changes have already occurred in the CalPX markets and the CAISO is currently examining ways to modify the markets that it operates[3]. The following discussion therefore pertains to the state of the restructured market at the time of writing. In its current state, the restructured market actually consists of five (6) separate but related markets operated by the CalPX and CAISO. The CalPX operates three forward markets (Day-ahead, Day-of and Block Forwards) for the sale of energy. The CAISO operates three markets (ancillary services, energy imbalance, transmission congestion) associated with its primary task of maintaining system reliability.

CalPX Market Descriptions

The CalPX operates three separate forward energy markets (Day-Ahead, Day-Of and Block Forwards markets). When the restructured California market first opened on April 1, 1998 the CalPX operated only its Day-Ahead energy market. Operation of an Hour-Ahead market began on July 3, 1998 and continued until January 17, 1999. On that date the Hour-Ahead market changed to the Day-Of market and the number of trades per day was reduced from twenty-four to three.

Day-Ahead Market

Each day by 7:00 a.m. CalPX Participants submit portfolio bids to buy and sell energy for each hour of the succeeding day. These portfolio bids are used by the CalPX to derive aggregate supply and demand curves. Using these curves the CalPX establishes an unconstrained market clearing price and quantity for each hour and identifies the successful bidders. Following the conclusion of the Day-Ahead auction, successful bidders must then provide the CalPX with specific information relative to their initial portfolio bid (quantity and location of loads and supplies within the grid) in the form of an Initial Preferred Schedule. The CalPX, along with other SCs provides these schedules (which are balanced with respect to supply and demand in each hour) to the CAISO. These schedules also include Participants' Ancillary Services Bids and Schedule Adjustment Bids.

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[3] This topic is covered in more detail in the "Market Surveillance Committee of the California Independent System Operator - Report on Redesign of Markets for Ancillary Services and Real-Time Energy" by Frank Wolak, et. al., March 25, 1999.

Having received schedule and associated bid information from all of the SCs (including CalPX) the CAISO then conducts its Ancillary Services market/auction and performs congestion management. Adjustments, if needed, are made to the initial preferred schedules and these suggested changes are provided to the SCs. The CAISO receives updated schedules from the SCs and issues Final Day-Ahead schedules including Ancillary Services requirements by 1:00 p.m. on the day prior to the day of delivery. The CAISO also publishes the final transmissions usage charge rates if transmission congestion has occurred. Using this information, the CalPX then calculates the Zonal Market Clearing Prices.

Day-Of Market

In the Day-Of market, buyers and sellers are able to adjust the positions they received in the Day-Ahead market in order to minimize real-time imbalances. Changing weather conditions or supply changes due to plant outages or line de-ratings can all result in a need for adjustment of the Day-Ahead schedule. In the original Hour-Ahead market, bids (unit specific bids) were submitted at least 2 hours before the hour of operation with a total of twenty-four hourly auctions each day. At the request of market participants this was changed to just three auctions per day occurring at 6 a.m., noon and 4 p.m.

The CalPX determines the MCP in the same way as the Day-Ahead Market and communicates price and traded quantities to participants immediately after the Day-Of market is closed.

Block Forwards Market

A CTS (CalPX Trading Services) Block Forwards Market contract is a standardized contract for delivery of on-peak (6 a.m. – 10 p.m., Monday through Saturday) energy during a calendar month. The contract provides for delivery of a specific amount of on-peak energy to a California delivery point. Trading of CTS Block Forwards Market contracts occurs each weekday from 6 a.m. – 10 a.m. when participants telephone the CTS trading desk to submit orders (bids and offers). The trading desk provides best bid and offer information and matches trades in a continuous bid and offer process.

CAISO Market Descriptions

The CAISO maintains three markets directly related to its primary task of maintaining system reliability. The Ancillary Services market provides the CAISO with sources of regulation, spinning reserve, non-spinning reserve and replacement reserves while the Imbalance Energy market enables the CAISO to “trim” resources to maintain the system-wide energy balance. The Transmission Congestion Management market facilitates CAISO management of inter-zonal transmission congestion.

Imbalance Energy Market (Real-Time Market)

The CAISO is responsible for balancing loads and resources in real-time in order to maintain a high quality and reliable supply of energy. To accomplish this requires that the CAISO be able to increment and decrement resources as needed to maintain a system-wide energy balance. The CAISO uses bids received in the Imbalance Energy market to determine the most cost-effective way to achieve this goal. Imbalance Energy market bids include Supplemental Energy Bids, which Participants provide to the CAISO up to one hour prior to the dispatch hour, as well as the energy bids submitted by Participants in conjunction with their Ancillary Services capacity bids (as described below). The Imbalance Energy market price is calculated in 10 minute intervals and price is used to settle deviations between scheduled and actual quantities of supply and demand. A Participant that over-delivers relative to its scheduled quantity is paid the imbalance price, while a Participant that under-delivers relative to its scheduled quantity is charged this price.

Ancillary Services Markets

The Ancillary Services market actually consists of four day-ahead and four hour-ahead capacity auctions. These auctions provide for CAISO access to generation capacity needed to insure reliable system operation. The four basic ancillary services covered by these auctions are: Regulation, Spinning Reserves, Non-Spinning Reserves, and Replacement Reserves. Unlike the energy markets operated by the CalPX, each of these markets is for capacity only[4]. Bids into the Ancillary Services market are relayed to the CAISO by Scheduling Coordinators along with the Day-Ahead schedule information.

Transmission Congestion Management

The Transmission Congestion Management market operates using Schedule Adjustment Bids (SAB) that are provided to the CAISO by SCs. SABs are basically the cost (to the CAISO) to increase or decrement a resource depending on price. As such SABs indicate the willingness of a SC to increment a resource based on price, and are an expression of the value that the SC places on obtaining inter-zonal transmission access. The CAISO uses SAB values to adjust individual resource schedules in order to relieve congestion and to subsequently calculate transmission congestion Usage Charge rates.

3.3 *Electric Distribution Operation, Cost and Performance Opportunities*

UDCs are regulated monopolies within the restructured electric market. The UDC's primary function is to provide reliable electric distribution services to all customers, including those with direct access, within its service territory. Broadly speaking, "distribution" includes all parts of an electric utility system between the point of bulk power delivery and the consumer's service entrance. Utilities typically design distribution feeders to operate in the range of 4.16 to 34.5 kV to supply load in a well-defined geographical area. Distribution system planning and design involves complex methods of load forecasting, circuit analysis and applied engineering economics.

[4] Each bidder must also submit an energy bid along with the ancillary service bid. The Energy Bids in the Regulation market are used for validation only while the Energy Bids for Spinning, Non-Spinning, and Replacement Reserves are used, along with Supplemental Energy bids, in the real-time Imbalance Energy market.

Distribution systems consist of breakers, conductors, transformers, fuses, capacitors, switches, monitoring and control systems, communication systems, above and underground structure assets. Figure 5 illustrates a typical primary distribution feeder.

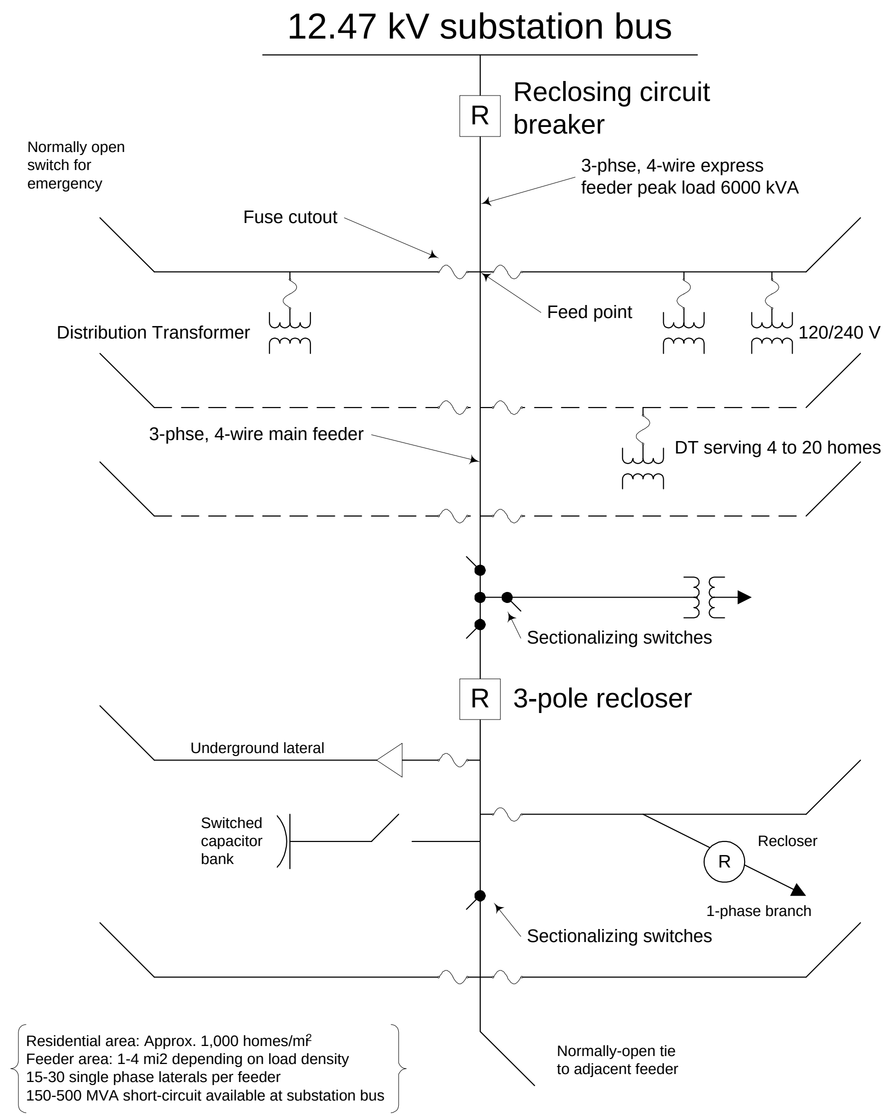

Figure 5 - One-line diagram of typical primary distribution feeder[5]

There are several considerations affecting distribution system planning: regional load growth, voltage, reliability, etc. Distribution planners have at their disposal a number of design options to meet specific situations. More specifically they can choose between radial and loop feeder design philosophies. Their ultimate goal is to meet service requirements at the lowest cost possible. However, reaching this goal is further challenged by the regulatory and economic environment changes resulting from electric market restructuring.

5 Reproduced from Fink and Beaty, Standard Handbook for Electrical Engineering, Eleventh Edition.

Recently the California UDCs have filed for performance based ratemaking (PBR) mechanisms for distribution service. In the SDG&E PBR filing decision the CPUC indicated the intent of PBR.

> We have long considered incentive-based ratemaking superior to command-and-control regulation. PBR rewards the UDC for achieving improved reliability at lower costs. PBR sends an important message to the UDCs that minimizing costs without sacrificing service quality and reliability can result in greater rewards with "less" regulation than traditional cost-of-service.[6]

PBR requires the establishment of a baseline revenue requirement for distribution service. Baseline revenue requirements are adjusted annually for inflation and productivity changes. Decreases in adjusted revenue requirements, that exceed a pre-defined range, result in an increase in stockholder earnings as long as various performance indicators do not deteriorate.[7] The performance indicators include; safety, reliability, customer satisfaction, call center responsiveness and certain customer service guarantees. Specifically reliability performance indicators include; system average interruption duration index (SAIDI), system average interruption frequency index (SAIFI) and momentary average interruption frequency index (MAIFI).

Several studies have identified power delivery cost and performance benefits derived from DER installations. Past studies by the Electric Power Research Institute (EPRI), Pacific Gas and Electric (PG&E) and others have identified benefits including; capital deferral, reduced energy loss and improved reliability. It appears that a direct connection exists between the DER potential benefits and UDC PBR mechanisms.

3.4 Electric Pricing / Retail Rates

Any discussion of the California competitive market would be incomplete without some discussion of how the new market affects the customer's bill for electricity. This is especially important in discussions related to DER operations since DER equipment has historically been owned or operated by customers whose primary contact with the competitive market is their monthly utility bill. Figure 6 shows the various entities and associated cost elements that impact an electric utility bill in the California electricity market.

As the figure shows the wholesale base price of electricity is the base upon which a large number of fees/charges are attached before electricity is ultimately delivered to the customer. These fees/charges are not unjustified since each represents payment for a service that is provided in order to eventually deliver the electricity to the customer. Some of the fees associated with an electricity bill are fixed while others are based on consumption (e.g., distribution and transmission charges, etc.). While we have tried to show the various cost adders on the figure it should be noted that not every fee is applicable for every customer. For instance, electricity provided to a residential customer

[6] CPUC Decision 99-05-030, "Application of San Diego Gas & Electric Company (SDG&E) for Authority to Implement a Distribution Performance-Based Ratemaking Mechanism", Filed January 16, 1998, Decided Many 13, 1999.
[7] Conversely, earnings can decrease when adjusted revenue requirements increase.

by the local UDC would not be subject to aggregator's fees or the fee of a separate SC. It is not our intent to define specific charges for different customers but to show that the price ultimately paid by the customer is significantly higher than the base electric price, with many of the fees tied directly to consumption.

So it can be seen that DER operation has the potential to provide benefits at both the retail (e.g., off-setting customer electric costs) and wholesale levels (e.g., sale of energy or capacity into one of the six competitive markets). How DER benefits are achieved and specifically what role the DER*S product would play in this process is a fundamental question that must be addressed before the DER*S product can be fully defined. We will address these issues in more detail in our discussion of DER benefits in Section 4.

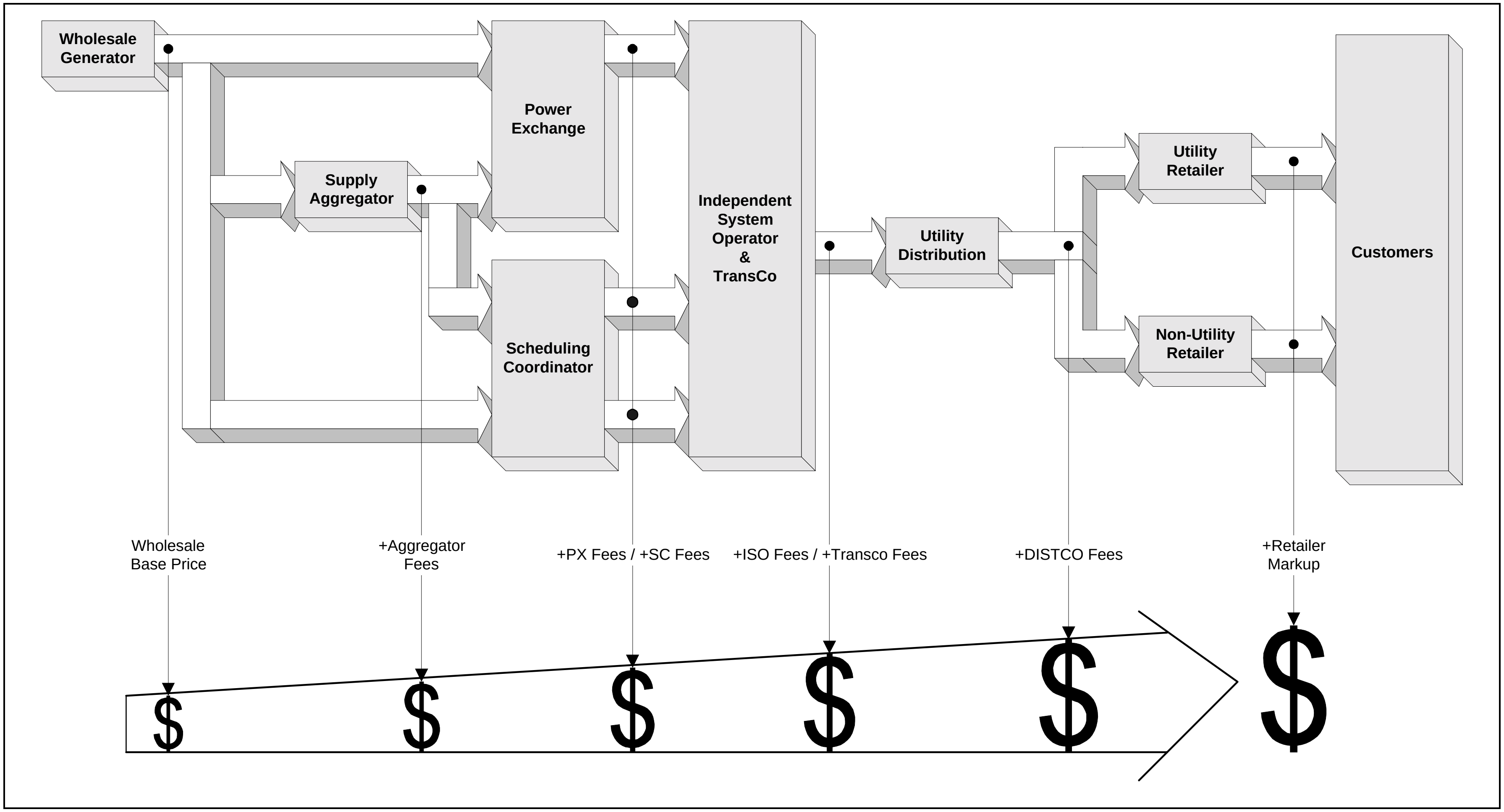

Figure 6 – Electric Price / Cost Contributors

4.0 DER Technology Description

This section provides an overview of DER technologies, their characteristics and their likely applications. A description of the DER technology characteristics and applications are useful in understanding the domain within DER will be applied and operate.

4.1 Definition of DER

The definition of DER is crucial in understanding technologies and applications that fit within its operational domain. At initial glance, a DER definition appears to be easily established. However, even a light treatment of details reveals multiple attributes of DER that are not easily established or agreed. The difficulty is rooted in the many related forms of DER (e.g., cogeneration, distributed generation, distributed utility etc.) some of which are defined only in close circles while others have well established public, albeit non-standard definitions.

For purposes of this project, we adopt a broad definition of DER whose essential characteristic is proximity to load. In this definition we do not limit DER capacity size and include end-use load management through energy efficiency and demand shifting. Later in this report, we will discuss the subset technologies and applications within the DER definition that are likely candidates for DER*S. the adopted DER definition, which is adapted largely from the California Alliance for Distributed Energy (CADER) is summarized below in Table 1.

Table 1 - Distributed Energy Resource Definition

<u>Definition of DER</u>
❖ Generates, stores or conserves electricity
❖ Located near or at a load center
❖ Can be grid connected or isolated
❖ Has a value greater than grid power including –
– Customer value
– Power delivery benefits
– Social or environmental value

4.2 DER Technology Classifications

DER technologies can be classified three broad categories: electric generation, energy storage and energy efficiency. We have further segmented each broad category into smaller categories that are more detailed. Table 2 provides a breakdown of the various DER categories.

Table 2 - DER Technology Classifications

❖ Electric Generation – Fossil Fuel ▪ Gas Turbines (GTs) ▪ Fuel Cell Power Plants ▪ Internal Combustion Engine/Generators (ICEs) – Renewable Fuel ▪ Photovoltaic Systems (PVs) ▪ Solar Thermal Electric ▪ Wind Turbines ▪ Small Hydro	❖ Energy Storage – Batteries – Flywheels – Thermal Energy Storage ❖ Energy Efficiency – Lighting – Motors – HVAC&R – Industrial Processes – Office Equipment ❖ Demand Side Management – Curtailable Loads

4.3 DER Technologies Most Applicable to DER*S

The DER*S technology, once developed, will be a sophisticated scheduler for distributed energy resources. DER*S is applicable to DER equipment that can be dispatched. Non-dispatchable technologies, such as wind, solar, and energy efficiency, are not compatible with DER*S because their production output is not easily controlled. However, in some DER technologies, the addition of energy storage *can* provide dispatching capability. Note that curtailable loads can be dispatched depending on the type of load involved. For example, air conditioner cycling by remote control is a dispatchable resource that could be bid into the ancillary services market as non-spinning reserve (available within 10 minutes). Loads (i.e., process loads, requiring additional advance warning could still be classified and scheduled/dispatched as replacement reserves (available within 60 minutes). Other DER technologies such as ultracapacitors and SMES provide short bursts (i.e., milliseconds) of electric energy to improve power quality. Although dispatchable these technologies are triggered by power quality events and do not affect the aggregate value of electric energy. Table 3 summarizes DER technologies that are dispatchable and, therefore, most compatible with DER*S.

Table 3 - DER Technologies Compatible with DER*S

DER Technology	Notes
Gas Turbines (GTs)	Generally dispatchable, but may be designed to operate as base load cogeneration or combine cycle. In DER base load operation, dispatch is not an option because the plant is constantly at maximum available output.
Fuel Cell Power Plants	
Internal Combustion Engine/Generators (ICEs)	
Photovoltaic Systems (PVs) w/ energy storage	Generally not dispatchable. However, the addition of energy storage or combining with other generating technologies can provide dispatching capability.
Solar Thermal Electric w/ co-firing capability and/or energy storage	
Wind Turbines w/ energy storage	
Small Hydro	Dispatchable, but is constraint by availability of sufficient hydro head.
Batteries	All energy storage is inherently dispatchable.
Flywheels	
Thermal Energy Storage	
Load Management / Curtailable Loads	Some curtailable loads such as air conditioner cycling is dispatchable while other loads require some advance notice. Loads requiring advance notice may be scheduled or bid as ancillary services (i.e., non-spinning reserve, replacement reserve)

4.4 DER Controls

In this project we are most interested, in the DER external interface controls that deal with DER unit commitment and dispatch. The various DER equipment types have numerous controls for internal process functions and external interface requirements. The nature and complexity of internal controls are dependent on the type of DER equipment. For example, internal combustion reciprocating engine generators have internal controls for fuel, air, ignition, cooling and electrical systems that provide shaft speed regulation, generator loading, engine thermal management, and other functions.

External interface controls are those systems that monitor and react to changes in the way the DER operates relative to external conditions. For example, fuel control pressure regulators in an engine or gas turbine must compensate for changes in natural gas supply pressure. Another example is electric grid interconnection operation and protection, which is important to all grid-connected DER technology applications.

A special subset of external interface controls are those that deal with DER unit commitment and dispatch. "Unit Commitment" is a decision to start a generator or storage system to serve a load. "Dispatch" means bringing the committed DER unit to a specific load point to minimize cost or maximize benefits. Historically, utilities have used these terms to describe central power plant operation in the bulk power markets. Industry has used these terms sparingly when talking about DER technologies. However, we find for purposes of this development project that these terms are appropriate when discussing DER scheduling and loading for net benefit maximization.

The control logic for the commitment and dispatch of DER assets is dependent on the nature of the DER application and designed service. We have summarized the typical types of DER service below.

1. *Emergency/Backup* - In this service, DER equipment remain in standby mode until needed to replace loss of grid supply. Commitment controls for this type of service require sensors to detect loss of grid and/or sudden voltage or frequency excursions. In many applications, time to start, stabilize and serve load is critical. For this reason, smaller load applications may use battery energy storage alone and larger applications may integrate engines and gas turbines with quick starting battery or flywheel energy storage devices to provide a complete uninterruptible power supply (UPS) system. These DER systems typically serve critical dedicated customer circuits that are isolated with automatic transfer switches. Dispatch controls are designed to fully service the dedicated circuits by load following. Because they operate isolated from the grid, interconnection and synchronous operation are not as much an issue as those DER that operate grid connected. This mode is also applicable to energy storage DER technologies.

2. *Peak Shaving* - This DER application serves to control the cost of electric energy by limiting the customer's net power consumption during relatively short periods of time. In many peak shaving applications, unit commitment is a function of time dependent electric rates (e.g., time-of-use or real-time pricing) and/or ratcheted demand charges. Utilities can also use peak shaving as a way to reduce excessive loads in stressed areas of their grids. This *load* clipping application is different from *price* clipping, but we consider both as forms of peak shaving service. The main difference between these two is the external signal that triggers the commitment of these DER units. Load clipping is a function of the magnitude of the local distribution load while price clipping is a function of the price of electricity. Dispatch control for these applications typically means bringing the DER unit to maximum output for the duration of the need. This mode is applicable to energy storage DER technologies.

3. *Load Following* - DER equipment operating in this mode are trying to maximize their capacity factor without exceeding local electric load resulting in unwanted power export or when a cogenerator is following thermal load so excess heat is not dumped. Load following is likely when excess power or heat decreases the economic attractiveness of the DER operation. Commitment control logic is trivial since the intent is to run the unit as much as possible unless local load goes completely to zero. Dispatch control requires following of local load without reversing power flow or producing excessive heat. This is applicable to storage DER technologies only when coupled with under sized dispatchable generator or non-dispatchable renewable generator such as wind or photovoltaics.

4. *Constant Loading* - Also known as base load operation, this DER operating mode sets the generator output at full power constantly. Many PURPA cogenerators are designed to operate this way. When the electric output of the cogenerator exceeds the local load, power is sold into the grid at utility avoided costs. In constant load operation, both unit commitment and dispatch control is trivial.

Aggregated operation for grid support is a special DER operating mode that can incorporate multiple DER assets at different sites. In recent years both hardware and software products have become available that allow for remote / centralized control of multiple DER assets for grid support purposes. Utilities and ESCOs initially installed these control systems so that emergency back-up generators (manual switchover, grid-isolated operation, etc.) could be grid-connected and centrally dispatched. RTU hardware and software installed on a generator or other DER asset provides both grid interconnection and safety systems while allowing for remote communication and control of the DER. Software packages at the central dispatch point provide dispatch of single or multiple units grouped by a variety of parameters as well as direct access to individual unit operating parameters. Additional hardware provides information on operating parameters vital to the centralized dispatch (i.e., output, operating temperatures, etc.). These products have been promoted to UDCs for use as additional capacity as an extension of their existing interruptible rate programs but are also seeing use for aggregation and bidding into the California ancillary services markets.

4.5 DER Controls Most Applicable to DER*S

It is apparent from the various DER*S operating scenarios described in Section 2 that communication with, and remote control of the DER asset(s) is essential to DER*S operation. Therefore, DER controls that provide remote communications and connectivity are more readily adapted to the DER*S approach. In addition, controls that provide safety features, grid interconnection and other fundamental unit operating requirements (i.e., cooling, lubrication, fuel control, etc.) would relieve the DER*S agency from providing these control functions. These intrinsic controls, by necessity, require fast response times and are typically handled by analog or high-speed digital controls. Scheduling and dispatch functions, on the other hand, do not have the same rapid response requirement. Thus, control of these high-speed functions outside of the DER*S agency would allow use of more conventional computing resources. Table 4 summarizes these and other characteristics that facilitate DER*S integration.

Table 4 – DER Control System Characteristics Compatible with DER*S

DER Control System Characteristic	Notes
Control of basic/intrinsic DER operating parameters (safety, grid-interconnection, cooling, lubrication, etc.)	These intrinsic DER functions are separate from the DER*S scheduling and dispatch functions.
Remote communications and control capabilities	Facilitates implementation of DER*S scheduling and dispatch instructions.
Compatible with a variety of building energy management systems (EMS)	Facilitates DER*S access to multiple on-site DER assets as well as sensors (i.e., ambient temperature, building load, etc.) and interfaces already connected to a site EMS.
Open software design allowing integration of 3rd party software modules.	Facilitates integration of DER*S software modules into the existing controls. Improves DER*S retrofit capability.

See Appendixes A and B for additional sample information on current DER control (OEM) and 3rd party control software products respectively.

4.6 DER Benefits

The type of benefit derived from DER applications depend on the beneficiary's perspective. A utility customer receives different benefits than a Utility Distribution Company, energy service provider or independent system operator. Indeed, the motivation for DER application is different for each market player. We have summarized potential benefits from DER application from each market player's perspective in Table 5 below.

Table 5– Summary of DER Benefits

Beneficiary	Potential DER Benefit
Energy Customer	Lower overall energy costs and increased power supply reliability. DER can accomplish this by supplying electric and thermal energy supplied locally to a customer or group of customers, or reducing the PX price of electricity to all customers by reducing system wide load.
Energy Services Company	Bundling of customer on-site DER services with power and fuel contracts to increase customer value and improve contract margins. DER can serve as an as arbitrage machine for customer electric supply or improve aggregate customer load shape to enhance power purchases.
Electric Distribution Company (regulated)	Improved power delivery reliability/efficiency, active line reactance control, asset utilization and deferment of infrastructure capital investment. Under PBR mechanisms UDC shareholders can profit by improved performance of the distribution system.
Independent System Operator (regulated)	Congestion relief and potential ancillary service resource.
Gas Distribution Company (regulated)	For natural gas fueled DER, increased natural gas fuel sales and improved asset utilization.

DER can be applied such that it is dedicated to one of these beneficiaries or interact with a number of beneficiaries. Figure 7 further illustrates the possible interactions that DER may have with various beneficiaries.

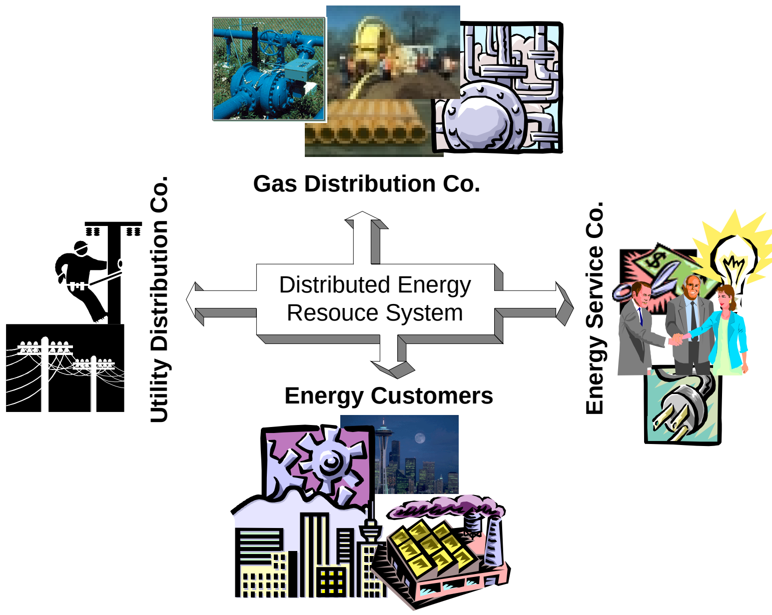

Figure 7 – DER – Beneficiary Interaction

How DER benefits flow to beneficiaries and *who* is paid for the benefit is dependent on DER ownership and the market involved. For example, strategically located DER may supply vital ancillary services through the ISO, which benefits all electric customers. The payments for this service would flow to the owner of the DER, which may be a customer, ESCO or even an UDC. Not all benefits receive payments. An example of this would be the reduction of PX electric price resulting from load reduction that benefits all electric customers that purchase from the PX. The cause of the reduction may be the operation of customer DER that reduces the net load to the grid.

4.7 DER Technology Characteristics

DER technology characteristics are discussed below.

Internal Combustion Engine/Generators (ICE)

ICE (a.k.a. reciprocating engine) generators have a long history as standby and remote electric generating plants. In the early 1970's ICE's become popular for cogeneration plants typically below 1 MW in capacity. ICE power plants are available from 50 kW to 5 MW capacity sizes in diesel and spark ignition configurations. They are primarily fueled with natural gas, diesel and gasoline. Some ICE plants are fueled with anaerobic digester gas, landfill gas and there are developments for coal fueled ICE power plants. An ICE cogenerator located in Chino, California is shown in Figure 8.

Figure 8 – 625 kW ICE Cogeneration Unit

Gas Turbines (GTs)

GT/generators are modified jet engines used for stationary electric generation. Simple cycle GT power plants come in wide range of sizes. Large GT plants can be as large as 200 MW in capacity and are popular in new combine cycle power plants. Medium size GTs range from 10 MW to 80 MW and are most popular in larger industrial cogeneration plants or partial repower projects. Small GT plants range from 1 MW to 10 MW in size and are used in industrial and large commercial cogeneration applications (see Figure 9). The newest GT power plant systems are microturbines that range from 25 kW to 500 kW in size (see Figure 10). Some GTs in the small to medium range are aeroderivative engines that have been adapted from jet aircraft engines. GTs are know to have a relatively high thermal to electric production ratios and can produce high temperature steam which makes them well suited for large thermal host applications.

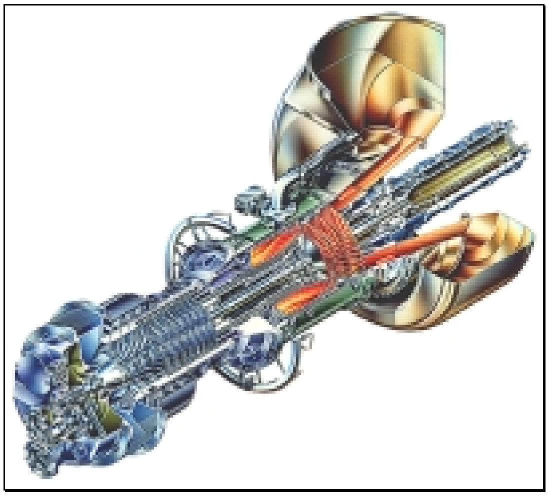

Figure 9 – Solar Turbines Centaur Gas Turbine

Figure 10 – Allied Signal 75 kW Microturbine

Fuel Cells

Fuel cells produce direct current electric power by combining fuel and oxidant in an electrochemical reaction. An inverter is used to convert the DC power into AC power that is compatible with the grid and/or load. There are five major types of fuel cells; phosphoric acid (PAFC), molten carbonate (MCFC), solid oxide (SOFC), proton exchange membrane (PEM) and alkaline fuel cells. The type of electrolyte used in the cell stack differentiates them. Alkaline fuel cells are used exclusively for aerospace applications such as the space shuttle. PAFC's are the most mature of the stationary fuel cell power plant technologies. PEM's are being developed for transportation and stationary applications. SOFC's and MCFC's are currently in development and demonstration stages. Fuel cells are fueled primarily with hydrogen[8]. Fuel processors are used to convert raw fuels, such as natural gas, into hydrogen rich fuel streams using steam reformation or partial oxidation processes. PAFC's have been operated on renewable fuels like landfill and digester gas.

Future advancements include multi-fuel processors allowing a wide variety of fossil fuels to be used for fuel cell power plants. Smaller fuel cell power plants targeted for residential and small commercial customers are being developed by Plug Power, a joint venture between Detroit Edison and Mechanical Technology Inc. They are currently in the demonstration phase of 5-10 kW fuel cell generators.

Figures 11 and 12 show examples of fuel cell power plants.

Figure 11 – ONSI 200 kW PC-25C Phosphoric Acid Fuel Cell Power Plant

[8] However, MCFC's and SOFC's have the capability of utilizing carbon monoxide as a fuel.

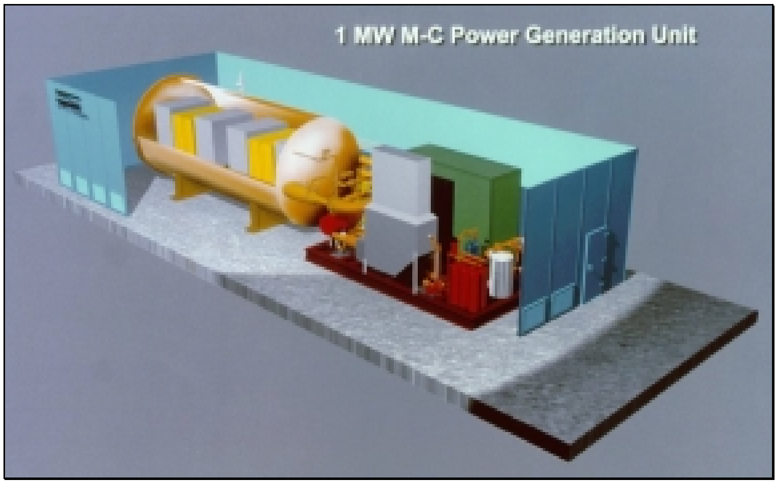

Figure 12 – M-C Power 1 MW Molten Carbonate Fuel Cell Power Plant

Photovoltaic Systems

Photovoltaics (PVs) convert solar energy directly into direct current electricity. Individual PV modules are commercially available in sizes from 10 W to 300 W. The actual power output may differ from module rated and depends upon the intensity (W/ft^2) of sunlight, the operating temperature of the module, and other factors. Additional electrical power conditioning components are required to interface the PV with the electrical load. Different semiconductor materials and techniques are used to fabricate PV cells. Some common types of cells include single-crystalline silicon, semi- or poly-crystalline silicon, thin-film crystalline and amorphous silicon cells. Tracking devices may be used to enhance the capture of sunlight energy. Compared to other modular generating technologies, such as fuel cells or ICE generators, PV systems require relatively large areas to obtain significant amounts of power. A typical one square meter flat panel PV system has a generating capacity of 50 W to 150 W assuming 1 kW/m^2 of incident solar radiation.

Figures 13 and 14 show residential PV systems.

Figure 13 – Photovoltaic Panels on SMUD Residential Customer Home

Figure 14 – Home with Uni-Solar Photovoltaic Shingles

Solar Thermal/Electric

There are three major types of solar thermal/electric generators; solar power tower, solar parabolic trough and solar dish Stirling engine. The most likely of these that would be used for self-generation is the solar dish Stirling engine. Dish/engine systems utilize concentrating solar collectors that track the sun in two axes. A reflective surface of metallic coated glass or plastic reflects incident solar radiation to small region called the focus. The engine determines the size of the solar concentrator for dish/engine systems. A 25 kW dish/Stirling system's concentrator has a diameter of approximately 10 meters. Currently a dish/Stirling system is being developed and demonstrated by Science Applications International Corporation (SAIC). SAIC and Stirling Thermal Motors, Inc. (STM) are working on next generation hardware including a third-generation which includes a faceted stretched membrane dish with a face-down-stow capability and a directly-illuminated hybrid receiver. Dish/Stirling systems are considered the most efficient way of converting solar energy to electricity. Figure 15 shows the SAIC dish Stirling system.

Figure 15 – SAIC 25 kW Solar Dish/Stirling System

Wind Turbines

Wind energy systems generate electricity by converting kinetic energy from moving air into torque that drives a generator. The two basic types of wind turbines are the horizontal-axis wind turbine (HAWT) and the vertical-axis wind turbine (VAWT). HAWT's are the most common. They consist of: (1) rotor with two or three blades, (2) a drive train coupled with an electrical generator, and (3) a tower and foundation supporting the rotor and drive train. Supporting subsystems include controls, electric power transfer cables and step-up transformer. The use of a electronic power converter (inverters) permit variable speed operation of the wind turbine and finer control over power quality. About 70% of all installed wind turbines in California are rated at 150 kW or less (CEC, 1993). However, the overall trend in the United States is toward larger turbines in the 200 kW to 500 kW range. Sixty-eight percent of new wind capacity installed in California in 1992 was 200 kW or larger. While no megawatt-scale wind turbines are currently being developed in the United States, such research and development is active in Europe. A small wind 10 kW turbine is illustrated in Figure 16.

Figure 16 – 10 kW Bergey Wind Turbine

Energy Storage Technologies

Electric energy storage converts electricity into a form that can be stored for conversion back to electricity when needed. The conversion of electricity into the storable form is referred to as “charging” and the conversion of the stored energy into electricity is called “discharging”. Storage devices are distinguished by characteristics of the stored energy: batteries store electricity electrochemically: flywheels store energy in kinetically: and thermal energy storage stores energy as heat sources or sinks. Each technology has different characteristics in its power density, power capacity and energy capacity. The chart below (Figure 17) shows power and energy density of various DER technologies including energy storage.

Battery storage systems are common in small capacity sizes. Large MW size facilities are much more scarce and the technology is still in development for practical widespread use. Figure 18 illustrates a packaged battery storage unit for commercial and industrial applications.

Flywheel systems have promising applications in automobile and locomotive transportation. There has been some discussion of developing flywheel systems for commercial and industrial customer applications. Figure 19 shows a typical flywheel system.

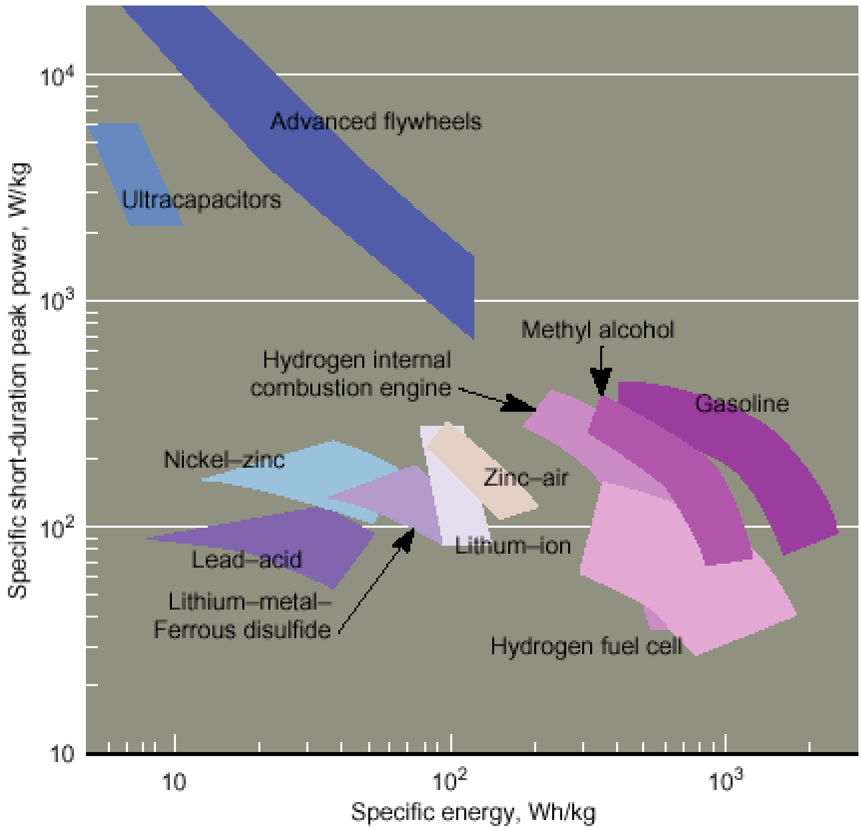

Figure 17 – DER Technology Power and Energy Densities

Figure 18 – Packaged Battery Storage System

Figure 19 – Example Flywheel Storage System

One method of thermal energy storage is to produce chilled water or ice during low cost off-peak electric rate periods and then use the heat sink during high cost electric rate periods to cool the customer's facility. Figure 20 shows a type of modular ice storage system used worldwide.

Figure 20 – Example Ice Storage System

Summary of Characteristics

The primary performance and cost characteristics of the various DER technologies are summarized in 6.

Table 6 – DER Technology Matrix

	DEVELOPMENT STATUS		OPERATION									
	Current Status (Dev, Demo, Comm)	Year Commercial	Rated Full Load Net Capacity (kWe)	Rated Minimum Load (%FL)	Useable Thermal Output (Btu/kWh)	Useable Thermal Temp. (F)	Operator?	Dispatch-able?	Practical Load Duty (Base, Interm., Peak)	Compatible Fuel(s)	Fuel Specifications	Cold Start-Up Time (minutes)
GENERATION												
Reciprocating I/Cs												
Diesel	Comm		50 - 5,000	50	3,400	185 - 900	No	Yes	B,I,P	Diesel	>2.0 psig	0.167
Otto (Spark Ignition)	Comm		50 - 6,000	50	1,000 - 5,000	316 - 500	No	Yes	B,I,P	Biogas, Natural Gas, Propane	1.0 - 45 psig	0.017 - 0.167
Gas Turbines												
Micro-Turbines	Dev/ Demo	1997 - 1999	25 - 250	0 - 50	4,000 - 15,480	400 - 635	No	Yes	B,I,P	Nat. Gas, Diesel, Propane, Multi-fuel	3 - 100 psig	0.5 - 1.0
Small Gas Turbines	Dev/Comm.	1999	500 - 10,000	5 - 50	3,400 - 12,000	500 - 1,100	No	Yes	B,I,P	Nat. Gas, Distillate, Biogas	140 - 500 psig	1.0 - 10.0
Fuel Cells												
Molten Carbonate	Demo	2000 - 2003	250 - 2,850	25 - 30	1,400 - 1,800	170 - 710	No	Yes	B,I	Nat. Gas	15 - 45 psig	1,200 - 2,400
Phosphoric Acid	Demo/Comm	1998	200	0	3,500 - 3,750	140 - 250	No	Yes	B,I	Nat. Gas, Propane	.15 - .5 psi	180
Proton Exchange Membrane	Dev/Demo	1998 - 2000	3 - 250	0 - 33	2,000 - 3,250	135 - 165	No	Yes	B,I,P	Nat.Gas, Propane, Butane, Diesel	gas pipeline press.	60
Hybrid Solid Oxide	Dev/Demo	2001 - 2003	225 - 2,240	25	540 - 1,100	350 - 420	No	Yes	B,I	Nat. Gas	None Reported	2 (see note)
Solar Electric												
Photovoltaics	Dev/Demo/Comm		10 - 10,000	0	0	0	No	No	P	Solar		0
Dish Stirling	Dev/Demo	1999	5 - 25	0 - 10	6,800	150	No	Yes (when fossil fueled)	B,I,P	Solar, Fossil Fuels	>300 W/m2	3 - 5
Wind Turbines												
<50 kW	Comm		0.85 - 50	1	0	0	No	No	P (w/ storage)	Wind	>8 MPH Wind	.08 - .16
>50 kW	Comm		50 - 1,000	1	0	0	No	No	I	Wind	>10 MPH Wind	0.16 - 0.5
STORAGE												
Batteries	Dev/Demo/Comm	1997 - 2000	100 - 20,000					Yes	B,I,P	Electricity	N/A	0 - .004
Flywheels	Dev/Demo/Comm	1997 - 2000	10 - 3,000	0 - 10	0	0	No	Yes	P	Electricity	N/A	0 - 40

Table 6 – DER Technology Matrix cont.

	MAINTENANCE		SITING & ENVIRONMENTAL								
	Time Before Intervention (opr hrs)	Time Between Overhauls (opr hrs)	Power Plant Size		Infrastructure Needs						Air Emission Controls
			Footprint (sqft/kW)	Volume (cuft/kW)	Weight (lb/kW)	Water Service	Waste Water Service	Fuel Delivery	Maint. Access	Telecom-munications	
GENERATION											
Reciprocating I/Cs											
Diesel	1,500 - 2,000	25,000 - 30,000	.22			Engine Coolant	No	Yes	Yes	Optional	None Reported
Otto (Spark Ignition)	280 - 1,000	24,000 - 60,000	.22 - .31	3 - 6	22 - 65	Engine Coolant	No	Yes	Yes	Optional	None Reported, SCR
Gas Turbines											
Micro-Turbines	750 - 10,000	5,000 - 40,000	0.15 - 1.5	0.6 - 4.0	2.6 - 37	None Reported	None Reported	Yes	Yes	Optional	None Reported, Catalytic
Small Gas Turbines	4,000 - 8,000	30,000 - 50,000	.02 - .61	.30 -1.06	7 - 26	None Reported	None Reported	Yes	Yes	Optional	None Reported, Water/Steam Injection, SCR, OLN Com b.
Fuel Cells											
Molten Carbonate	720	40,000	1 - 4	8 - 40	120 - 240	Yes or Can Be Self Sufficient	Yes or No	Yes	Yes	Optional	None Reported
Phosphoric Acid	2,200 - 8,760	40,000	4	40	200	None Reported	None Reported	Yes	Yes	Yes	None Reported
Proton Exchange Membrane	8,700	8,700 - 40,000	0.6 - 3	4.7 - 9	100 - 300	Possible	None Reported	Yes	Yes	Optional	None Reported
Hybrid Solid Oxide	8,000	40,000	1.1 - 1.2	18 - 20		None Reported	None Reported	Yes	Yes	Optional	None Reported
Solar Electric											
Photovoltaics			538			None	None	No	Yes	Optional	None
Dish Stirling	8,000	30,000	160 - 269		600	None	None	No	Yes	No	Low NOx Burner
Wind Turbines											
<50 kW	30,000	200,000	1.5 - 9.0	9 - 24	330 - 720	None	None	No	Yes	No	N/A
>50 kW	4,000	130,000	0.24 - 110		250	None	None	No	Yes	Optional	N/A
STORAGE											
Batteries	8,700		1 - 7		124 - 186	None	None	Yes (Electricity)	Yes	Optional	N/A
Flywheels	8,700 - 18,000	10,000 - 175,000	.013 - .830	0.5 - 6.0	1.3 - 17	None	None	Yes (Electricity)	Yes	Optional	N/A

Table 6 – DER Technology Matrix cont.

	SITING & ENVIRONMENTAL										PERFORMANCE					
	Air Emissions (lb/kWh, unless indicated otherwise)					Noise (dB @ ? ft)	Water Consumption (Gal./kWh)	Waste Water Production (Gal./kWh)	Hazardous Materials	Other Hazards	Net Electric Heat Rate (HHV Btu/kWh)			Expected Availability (%)	Typical Forced Outage Rate (%)	Load Ramp Rate (kW/min)
	CO	NOx	SOx	UHC	PM10						Full Load (100% FL)	Reduced Load (75% FL)	Mid-Load (50% FL)			
GENERATION																
Reciprocating I/Cs																
Diesel		.022 - .025				60 - 85 dB @ 23 ft	Nearly Zero Reported	Zero Reported	None Reported	None Reported	7,900 - 9,500		9,158 - 10,989	90	1	
Otto (Spark Ignition)	0.004 - 0.006	0.0015 - 0.037	0.0	0.0009	0.0002	100 @ 3.3 ft	Nearly Zero Reported	Zero Reported	None Reported	None Reported	9,300 - 11,800	9,600 - 11,000	10,200 - 11,400	97 – 98	1	250 - 1,000
Gas Turbines																
Micro-Turbines	3 - 50 ppm	3 - 50 ppm	Negligible	3 - 9 ppm	Negl.	<60 dB @ 33 ft or <60 dB @ 10 ft	Zero Reported	Zero Reported	None Reported	Batteries	10,300 - 16,484	11,300 - 17,000	12,200 - 25,043	92 - 98+	1 - 5	25 - 250
Small Gas Turbines	<15 - 50 ppm	.007 - .009 <9 ppm	Negligible	<15 - 25 ppm	Negl.	60 – 85 @ 23 ft or 85 dB @ 3 ft	Zero Reported	Zero Reported	None Reported	None Reported	8,400 - 16,000	9,000 - 11,000	9,850 - 12,200	90 – 98	1 - 3	
Fuel Cells																
Molten Carbonate	0.00001	<0.000002	<0.000003	Negligible	Negligible	60 dB @ 30 ft or 60 dB @ 100 ft	0 - 0.125	0 - 0.044	None Reported	None Reported	6,545 - 7,580	6,270 - 8,040	6,100 - 9,090	>95	<5%	7 - 285
Phosphoric Acid	0.000023	0.000016	0	0.0000004	0	62 dB @ 30 ft	Zero Reported	Zero Reported	None Reported	None Reported	9,450	9,450	9,450	97.7	1.2	80 kW Instantaneous
Proton Exchange Membrane	Negl.	Negl.	0	0	0	50 dB @ 6 ft 65 dB @10 ft	0 - 0.2	Zero Reported	Batteries	None Reported	9,492 - 9,763	9,235 - 9,492	8,543 - 9,492	>95	<1	0.5
Hybrid Solid Oxide	0.0	0.00005 - 0.00006	0	0	0	60 dB @ 30 ft	Zero Reported	Zero Reported	Spent Desulfurizer Reagent	None Reported	5,380 - 6,120	6,110 - 6,640	6,240 - 6,670	94	4	
Solar Electric																
Photovoltaics	0	0	0	0	0	0	0	0	None	None Reported	22,780 solar to electric					
Dish Stirling	.02	.02				Negligible	0	0	Hydrogen	None Reported	8,400 - 16,600	11,000 - 18,500	16,700 - 21,500	95		
Wind Turbines																
<50 kW	N/A	N/A	N/A	N/A	N/A	58 - 64 @ 100 ft	0	0	Batteries	None Reported	N/A	N/A	N/A	95 - 99	0 - 1	N/A
>50 kW	N/A	N/A	N/A	N/A	N/A	45 dB @ 820 ft	0	0	Hydraulic Fluid	Aviary Hazard	N/A	N/A	N/A			N/A
STORAGE																
Batteries							0	0	Low Risk VRLA Batteries	None	N/A	N/A	N/A	100%	0 - 0.55%	Nearly Instantaneous
Flywheels						0 - 68 dB @ 3 ft	0	0	None	high energy rotor	N/A	N/A	N/A	>95%	0	Nearly Instantaneous

Table 6 – DER Technology Matrix cont.

	ECONOMICS						POWER QUALITY			ENERGY STORAGE			
	Installed Capital Cost ($/kW)	Installation Cost ($/kW)	Fixed O&M ($/kW-yr)	Variable Non-Fuel O&M ($/kWh)	Power Plant Life (yrs)	Construction Lead Time (months)	Voltage THD (%)	Current THD (%)	Full Load Power Factor	Stored Energy Capacity (kWh)	Discharge/Charge Efficiency (%)	Stand-By Losses (% cap/hr)	Time-to-Charge (hrs)
GENERATION													
Reciprocating I/Cs													
Diesel	200 - 250	50 - 100		.005	30	3 - 12				N/A	N/A	N/A	N/A
Otto (Spark Ignition)	200 - 800	50 - 100	1.6 - 11.4	0.007 - 0.011	25 -35	8 - 9	5	5	0.8 - 1.0	N/A	N/A	N/A	N/A
Gas Turbines													
Micro-Turbines	250 - 1,250	35 -150		0.002 - .010	5 - 20+	0 - 1	<5%	<5%	0.8 - 1.0	N/A	N/A	N/A	N/A
Small Gas Turbines	300 - 870	50 - 120		.002 - .008	20 - 50	3 - 16				N/A	N/A	N/A	N/A
Fuel Cells													
Molten Carbonate	815 - 1,900	100 - 435	70	.003	30 - 35	12 - 24	<3%	<3%	0.85 - 1.0 lead or lag	N/A	N/A	N/A	N/A
Phosphoric Acid	3000	450 -750		.008 - .010	20	7	<3% balanced linear load		.85 lead or lag	N/A	N/A	N/A	N/A
Proton Exchange Membrane	4,000	1,000		0.010 - 0.045	15 -25	1	<5%	<5%	.8 lead or lag	4	40		4
Hybrid Solid Oxide	1,150 - 1,300	180 - 230	25 - 50	.002 - .003	30	3 - 6	Per IEEE Specs.	Per IEEE Specs.	1.0	N/A	N/A	N/A	N/A
Solar Electric													
Photovoltaics	5,000 - 10,000			.001 - .004						N/A	N/A	N/A	N/A
Dish Stirling	3,800 - 4,000			.05 - .025		1	0.5	0.5		N/A	N/A	N/A	N/A
Wind Turbines													
<50 kW	2,600 - 4,600	1,000 - 4,000			30	2	0.03	0.05	0.98				
>50 kW	850 - 1,500	60 - 175	4.2 - 70	.003 - .021	20 - 25	8 - 12			leading or lagging controller	N/A	N/A	N/A	N/A
STORAGE													
Batteries	620 - 1,250	200 - 416	10 - 42	.0076	30	9 - 12	<5	<5	variable	1,600 - 4,300	74 - 85	0 - 1	6 - 8
Flywheels	150 - 900	30 - 480	4 - 5		10 - 30	1 - 12	<5	<5	.90 - .98	1 - 2,000	82 - 90	<1	0.1 - 1.3

Appendix A: Sample Specification Sheets for Caterpillar DG Controls[9]

[9] Refer to Caterpillar website for updated materials: http://www2.cat.com/cgi-bin/frameset.pl?nav=products&content=/products/

Appendix B: Sample Specification Sheets for ENCORP DG Control Software & Hardware[10]

[10] Refer to ENCORP website for updated materials: http:/www.encorp.com/support/body_support.html

Appendix III
Virtual Evaluation Group Participants

Appendix C. Virtual Evaluation Group Participants

Type	Name	Association	Position
DG & Control Mfg	Mark Skowronski	Honeywell (formerly Allied Signal Power Systems, Inc.)	
ISO	Dave Hawkins	CAISO	Principal Engineer
DG Mfg	Eric Wong	Caterpillar	Product Consultant
UDC	Carlos Martinez	Southern California Edison	Manager
Ctrl Supplier	Scott Castalaz	Encorp	VP Marketing
Ctrl Supplier	David Wolins	EnFlex	VP Marketing
Researcher	Chris Marnay	Lawrence Berkeley National Laboratory	Staff Scientist
Loc Gov	Kurt Kammerer	San Diego Regional Energy Office	Director
UDC	Vic Romero	SDG&E	
Individuals listed below were approached after formation of the initial evaluation group & expressed an interest			
Ctrl Supplier	Rich Weiss & Ken Brickner	Engage Networks	National Sales Manager
Ctrl Supplier	Charles DeWitt	C3 Communications, Inc.	Manager, New Service Offerings
Ctrl Supplier	Pat McMillan	Sixth Dimension	Director -- Product Marketing
Ctrl Supplier	Mark Czopek	HESI	Sr Consultant - Business Development
Ctrl Supplier	Jim Moeller	Stonewater Software Inc.	Acct Manager
Hardware Supplier	Jay Tucker	ASCO	Sr Field Sales Engr
Ctrl Supplier	David A. Cohen	Silicon Energy	Director -- Business Development
Hardware Supplier	Mark Shiira	Kohler	Director -- Switchgear Systems

Appendix V
Follow-on Effort Summary

PROPOSED FOLLOW-ON EFFORT(S) SUMMARY

CURRENT PROJECT INFORMATION

NUMBER: **500-98-040**

PROJECT NAME: **INTELLIGENT SOFTWARE AGENTS FOR CONTROL & SCHEDULING OF DISTRIBUTED ENERGY RESOURCES**

PROPOSED FOLLOW-ON PROJECT GOALS:

The technical & economic goals of the proposed follow-on effort are to:

- Update the *Smart**DER product specification based on feedback received during the Phase I effort as well as changes that have occurred in the California energy marketplace.
- Identify and enlist participation by one or more potential commercialization partners that will integrate *Smart**DER into their technology.
- Refine *Smart**DER technology to reflect changes in the product specification and to provide interfaces with commercialization partner(s) software.
- Complete a successful feasibility test assessment of *Smart**DER technology scheduling/controlling actual loads and/or distributed generation assets in the "real world" California marketplace.
- Negotiate with one or more partners for continued commercialization of *Smart**DER technology.

PROJECT RELEVANCY

Deregulation in California was in its formative stages in 1998 when the original Phase I effort was proposed. At that time it was already apparent that distributed energy resources (DER), such as distributed generation and curtailable loads could play a significant role in the marketplace. CADER (California Alliance for Distributed Energy Resources) summarized these benefits as follows:

- Improved system reliability, power quality, VAR control, and reduced reliance on must-run generation
- Reduced distribution system congestion, avoidance of distribution line losses and deferral of system upgrade/construction
- Customer cost reduction by direct displacement of load
- PX market clearing price (MCP) reduction (new DER reduces overall system demand which displaces the highest cost resource)

CADER projections indicated that DER technology could supply 20% - 40% of the estimated capacity that would be needed in California in the ensuing years to both replace retired generating plants and to meet increased loads.

It was also clear that while DER assets could play a significant role in this environment there were significant barriers to the use of a technology that relies on control and scheduling of large numbers of distributed assets. The centralized decision and control paradigm employed in the electric power industry was ill suited to this task. Use of intelligent software agents with their ability to collaborate thus distributing the decision process is well suited to this task. The Phase I effort addressed the difficulty in introducing this new paradigm to the power industry by demonstrating the viability of this approach as well as providing demonstration software that could be used to facilitate technology transfer.

One need only look at the daily newspaper to understand the dynamic nature of the California marketplace. There is little question that integration of DER assets into the marketplace has become of paramount importance. In 1998 there were four basic avenues for DER interaction in the deregulated marketplace. First, DER assets could be used to offset site loads to provide cost savings associated with utility bill reduction. Secondly DER assets could be used in conjunction with UDC sponsored interruptible rates. Third, DER assets, if aggregated in sufficient numbers, could bid into the energy spot market run by the Cal PX. And fourth, aggregated DER assets could participate in the ancillary services auction run by the California ISO. Specific procedures and protocols for DER participation in the marketplace did not exist at the time the Phase I effort was proposed. A great deal of progress has been made in the development of these procedures and protocols since the Phase I effort began in May 1999. The energy spot market and the CalPX itself no longer exists[1] but there are now five separate programs, either in place or pending that will provide for participation by DER assets. These programs now include:

- CAISO ancillary services (AS) auction (Supplemental energy, ancillary services),
- UDC sponsored interruptible rate tariff participation,
- CAISO DRP (demand relief program) (new program for 2001),
- CAISO DLCP (discretionary load curtailment program) (new program for 2001),
- CEC Electricity Peak Load Efficiency Grant Program (AB970) (new program for 2001),

Each of these programs has different requirements for participation, varying communication procedures and different verification/reporting requirements. Coordination of DER assets, especially in cases where aggregation of large numbers of assets is necessary has increased in importance. Clearly our efforts to facilitate integration of DER assets into the California marketplace are now more important than ever.

EXISTING PROJECT BACKGROUND:

The overall goal of the existing PIER project is to demonstrate the viability of using intelligent software agents for control and scheduling of one or more distributed energy resources (e.g., distributed generation, energy storage, cogeneration, etc.) in a competitive market. An intelligent agent is a software-based device that acts on behalf of the user and has the ability to exploit knowledge, tolerate errors, reason with symbols, learn and reason in real time, and communicate in an appropriate language. This will facilitate insertion of intelligent software agent technology into the energy industry

[1] The CalPX announced that it would cease operations in April 2001.

with its associated benefits. One of these benefits is to facilitate the coordinated scheduling of multiple distributed energy resource assets. Another is to reduce the level of expertise needed to own and operate distributed energy resources, which will in turn, allow greater participation by owners of distributed energy resources in California's competitive energy industry.

Current Project Objectives

The technical & economic objectives of the existing project are to:

- Demonstrate how a prototype network of intelligent software agents can coordinate and schedule one or more distributed energy resources.
- Develop a demonstration package that will facilitate transfer of the project results into the private sector.
- Identify and initiate discussions with one or more potential partners who are willing and able to participate with commercialization of the DER*S agency.

Current Project Status

The existing project is nearing completion with all milestones and deliverables due for completion by February 2001. At that time, the following items will have been completed.

- A Project Final Report and Final Presentation/Software Demonstration will be provided.
- Demonstration software will be delivered to the Commission and will initially be made available to interested parties via a dedicated WebPage. This demonstration software will allow the user to set up one or more simulated sites with multiple DER assets, select a time period during 1999 and observe the software agents collaborating to achieve appropriate operating schedules.
- AESC will have identified 10 – 12 companies that have expressed an interest in moving forward in some fashion with intelligent agent technology.

PROPOSED FOLLOW-ON EFFORT DESCRIPTION:

Intelligent agent technology represents a fundamentally different way of addressing the DER asset-scheduling problem. Use of intelligent agent technology provides for a distributed decision-making solution where centralized decision making processes are currently being applied. This fundamental shift in thinking makes the job of transferring this technology into the private sector more difficult since it requires that potential users change the way that they view the problem (and solution). The existing project was structured to address this issue and once completed will provide the basic tools (e.g., Test report(s), Demonstration Software) needed to facilitate the transfer this technology.

The existing project brings this technology to a Stage 3 (Bench testing/proof of concept) level of development and also provides tools that facilitate acceptance of this new technology. The proposed follow-on efforts are structured to move this technology beyond Stage 3 and addresses issues related to selecting the correct path (and associated partners, if any) for moving this technology into the marketplace. The following sections describe the four activity areas[2] of the proposed follow-on effort.

[2] Additional information on specific tasks and associated deliverables within each activity area will be provided should the commission express an interest in pursuing the follow-on effort.

Activity Area 1: Review and Evaluate the Feedback from the Phase I Effort.

The current project (Phase I effort) provides for development and delivery of demonstration software to the Commission but does not provide for continued refinement and support after delivery. Successful use of this software in the field is very important to eventual acceptance of this technology since it represents the first exposure that many potential partners and end-users will have to this technology. During the Phase I effort we enlisted the support of a Virtual Evaluation Group of individuals and companies working in the energy industry. At the end of the Phase I effort we provided the demonstration software and supporting materials to the Virtual Evaluation Group for use and review. Therefore, the first task of this Phase II follow-on effort provides support for both use and testing of the demonstration software by the Virtual Evaluation Group and for distribution of the software to other interested parties during a 2 – 3 month trial period. At the conclusion of this trial period we will evaluate the feedback of the evaluation group as well as review changes in the energy marketplace and identify any product modifications or enhancements.

Activity Area 2: Identify Feasibility Field Test Participants

Eventual integration of *Smart**DER technology into the marketplace can take a number of paths. There are a large number of "players" involved in the DER asset marketplace (i.e., generation equipment manufacturers, energy management, system equipment manufacturers, communication software developers, etc.) that could have an interest in participating in further development and testing of *Smart**DER technology. AESC engaged several potential partners during the current project via the Virtual Evaluation Group and also attended a number of conferences (CADER) and meetings (CAISO) during the course of the project. Over a dozen companies expressed an interest in our technology as a result of these efforts. However, expressing an interest and actually committing to technology can be two different things. The problem lies in identifying which of the interested parties provides the best opportunity.

*Smart**DER technology and the agent-based decision making capability that it represents is one piece of a large and dynamic puzzle. Ultimately, for Smart*DER technology to make a significant impact on the energy marketplace it must be able to interface with a wide variety of equipment (i.e., generators, energy management systems, etc.) and external entities (i.e., schedule coordinators, CAISO, CalPX, etc.) each of which has its own interface requirements. The existing project was structured to provide proof of concept and to facilitate acceptance of this new technology by providing demonstration software. It would have been both cost prohibitive and premature to develop various equipment interfaces so this type of development was not included in the existing project.

The tasks associated with this activity area will expedite further development and subsequent insertion of this technology into the marketplace by:

- Identifying and selecting one or more field test participants for our technology that will improve our ability to quickly insert *Smart**DER technology into the marketplace.
- Expediting development of interface software allowing our technology to operate with a wide variety of equipment in the marketplace.

To facilitate further commercialization only field test partners committed to the advancement of this technology will be selected. In addition, identifying potential field test sites will be the responsibility of the potential partners that wish to participate and each participant will be responsible for identifying the interface requirements and associated modifications to make their software/hardware compatible with *Smart**DER technology

Activity Area 3: Technology Refinement & Integration

The tasks associated with area of activity provide for refinement of *Smart**DER technology in response to product specification changes resulting from virtual evaluation group feedback and on observed changes in the energy marketplace. Interface refinements necessary for communication with field test partner products will be also be included.

Activity Area 4: Feasibility Field Test For Control of Actual Loads.

Basically, this area of activity provides for a feasibility field test of, the overall objective of which is to gather information on agent-based scheduling and aggregation of actual DER assets (distributed generation and curtailable loads) in a "real-world" dynamic environment. A large and successful feasibility field test will provide the necessary data on potential savings to entice customers to integrate this new technology into their operations. In addition, demonstrating feasibility will convince potential partners that a real and immediate need for this technology exists.

Activity Area 5: Project Management and Reporting

Tasks associated with this activity area encompass all of the management and reporting functions (i.e., kickoff meeting, monthly reporting, final report, etc.). AESC will continue to provide project management and reporting services as its matching contribution while other test participants (potential partners).

PROJECT BUDGET FUNDING AND SCHEDULE

It is anticipated that this effort would require 15 – 18 months to complete assuming one full year of field test activities (operation and monitoring). Should the Commission express an interest in pursuing the proposed effort, AESC will prepare formal descriptions and associated cost estimates for each task. However, as currently envisioned the Phase II Phase II follow-on will require less funding than the current project. Costs will vary depending feasibility field test duration and the number of participating sites. However for preliminary budgetary purposes it is anticipated that the cost of this effort will not exceed $500,000.